REPORT

OF THE

FIRST ANNUAL HARD SPRING WHEAT

CONFERENCE

HELD AT THE

NORTH DAKOTA AGRICULTURAL COLLEGE
FARGO, NORTH DAKOTA

MARCH 27, 1928

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PROGRAM OF THE FIRST ANNUAL WHEAT BREEDING CONFERENCE HELD IN THE GREEN ROOM, SECOND FLOOR OF MAIN BUILDING, AT THE NORTH DAKOTA AGRICULTURAL COLLEGE, FARGO, NORTH DAKOTA MARCH 27, 1928.

9:00 to 10:00; Informal gathering, Green Room.
10:00; Opening of Conference.
12:30; Luncheon, Lincoln Log Cabin, courtesy North Dakota Agricultural College.
1:30; Continuation of Conference.
6:30; Dinner at Commercial Club, courtesy Fargo Chamber of Commerce to out-of-town guests.

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LIST OF THOSE IN ATTENDANCE

Dr. Olaf S. Aamodt	Associate Pathologist, U. S. Department of Agriculture, University Farm, St. Paul, Minn.
Mr. Berry H. Akers	Editor, The Farmer, St. Paul, Minn.
Mr. Ole Arnegard	Farm Manager, Hillsboro, N. Dak.
Prof. A. C. Arny	Associate Agronomist, University Farm, St. Paul, Minn.
Mr. E. R. Ausmus	Junior Agronomist, U. S. Great Plains Field Station, Mandan, N. Dak.
Dr. C. H. Bailey	Professor of Agricultural Biochemistry, University Farm, St. Paul Minn.
Dr. C. R. Ball	Senior Agronomist, Office of Cereal Crops and Diseases, U. S. Department of Agriculture, Washington, D. C.
Mr. C. A. Bell	State Mill, Grand Forks, N. Dak.
Mr. C. H. Belting	DeLaval Separator Company, Chicago, Ill.
Mr. J. M. Birkeland	Research Assistant, Experiment Station, State College Station, Fargo, N. Dak.
Mr. R. H. Black	In Charge of Grain Cleaning Investigations, U. S. Department of Agriculture, Minneapolis, Minn.
Prof. H. L. Bolley	State Seed Commissioner, State College Station, Fargo, N. Dak.
Mr. E. G. Booth	Extension Agronomist, Experiment Station, State College Station, Fargo, N. Dak.
Dr. Andrew Boss	Vice-director, Experiment Station, University Farm, St. Paul, Minn.
Mr. L. W. Boyle	Ass't. Plant Pathologist, U. S. Department of Agriculture, State College Station, Fargo, N. Dak.

Mr. W. E. Brentzel	Plant Pathologist, Experiment Station, State College Station, Fargo, N. Dak.
Mr. W. J. Church	Board of Administration, Bismarck N. Dak.
Mr. Geo. F. Clark	Market Gardener, Fargo, N. Dak.
Mr. W. E. Clark	Farm Manager, Tower City, N. Dak.
Mr. J. A. Clark	Agronomist in Charge of Western Wheat Investigations, U. S. Depratment of Agriculture, Washington, D. C.
Dr. J. L. Coulter	(Presiding Officer), President, N. Dak. Agricultural College, Fargo, N. Dak.
Mr. Willis L. Crites	Farm Manager, Fargo, N. Dak.
Mr. A. J. Dexter	Agricultural Agent, Northern Pacific Railway, St. Paul, Minn.
Mr. F. E. Diehl	Board of Administration, Bismarck, N. Dak.
Dr. J. T. E. Dinwoodie	Editor, Dakota Farmer, Aberdeen, S. Dak.
Mr. R. S. Dunham	Agronomist, Northwest Experiment Station, Crookston, Minn.
Dr. E. M. Freeman	Dean, College of Agriculture, University Farm, St. Paul, Minn.
Mr. W. H. Gooch	Minnekota Elevator Co., Minneapolis, Minn.
Mr. N. D. Gorman	County Agent Leader, State College Station, Fargo, N. Dak.
Dr. C. H. Goulden	Senior Cerealist, Dominion Rust Research Laboratory, Winnipeg, Can.
Mr. M. A. Gray	Chief Chemist, Pillsbury Flour Mills Company, Minneapolis, Minn.
Mr. H. M. Harden	Editor, Farmstead, Stock and Home, Minneapolis, Minn.

Mr. J. W. Haw	Director, Department of Development, Northern Pacific Railway Co., St. Paul, Minn.
Dr. H. K. Hayes	Professor of Plant Genetics, University Farm, St. Paul, Minn.
Mr. W. C. Helm	Russel-Miller Milling Company, Minneapolis, Minn.
Mr. Harry Howland	Manager, Fargo Bakery Company, Fargo, N. Dak.
Dr. A. N. Hume	Agronomist, State College, Brookings S. Dak.
Mr. E. F. Johnson	General Agricultural Agent, Soo Railway, Minneapolis, Minn.
Dr. J. A. Kitchen	Commissioner of Agriculture and Labor, Bismarck, N. Dak.
Mr. Fred H. Loomis	Grand Forks, N. Dak.
Mr. M. M. McCabe	Duluth, Minn.
Mr. M. A. McCall	Agronomist in Charge of Cereal Agronomy, U. S. Department of Agriculture, Washington, D. C.
Mr. E. S. McFadden	Farmer and Plant Breeder, Webster, S. Dak.
Mr. Clyde McKee	Professor of Agronomy, State College Station, Bozeman, Mont.
Mr. H. A. McNutt	Agricultural Agent, Soo Line, Bismarck, N. Dak.
Mr. W. H. Magill	Fargo Seed House, Fargo, N. Dak.
Mr. C. E. Mangels	Cereal Chemist, State College Station, Fargo, N. Dak.
Mr. George C. Mayoue	Field Agent in Plant Pathology, U. S. Department of Agriculture Fargo, N. Dak.
Mr. H. W. Miller	Atwood-Larson Co., Minneapolis,Minn.
Mr. E. H. Mirick	Pillsbury Flour Mills Co., Minneapolis, Minn.

Mr. C. F. Monroe	Director of Extension, State College Station, Fargo, N. Dak.
Mr. C. C. Morrison	Agricultural Department, Great Northern Railway Co. St. Paul, Minn.
Mr. Paul C. Newman	U. S. Agricultural Statist, Grand Forks, N. Dak.
Mr. P. J. Olson	Assistant Agronomist, Experiment Station, Fargo, N. Dak.
Mr. W. C. Palmer	Agricultural Editor, State College Station, Fargo, N. Dak.
Mr. T. C. Roberts	Washburn-Crosby Co., Minneapolis.
Mr. Thos Sanderson	Miller, Exp. Sta. Fargo, N. Dak.
Dr. R. C. Sherwood	State Testing Mill, Minneapolis.
Governor A. G. Sorlie	Bismarck, N. Dak.
Dr. E. C. Stakman	Professor of Plant Pathology, University Farm, St Paul, Minn.
Mr. T. E. Stoa	Ass't. Agronomist, Exp. Sta. Fargo, N. Dak.
Mr. Ralph W. Smith	Assoc. Agronomist, Dickinson, N. D.
Dr. P. F. Trowbridge	Director, Experiment Station, State College Station, Fargo, N. D.
Mr. E. M. VanArman	Retired Farmer, Fargo, N. Dak.
Mr. C. B. Waldron	Prof. of Horticulture and Forestry, State College Station, Fargo, N. D.
Dr. L. R. Waldron	Plant Breeder, Exper. Station, State College Station, Fargo, N. D.
Dr. H. L. Walster	Dean of Agriculture, State College Station, Fargo, N. Dak.
Mr. W. T. G. Wiener	Cerealist, Man. Agricultural College Winnipeg, Man.
Mr. R. P. Woodworth	Secretary Woodworth Elevator Co. Minneapolis, Minn.
Mr. A. F. Yeager	Horticulturist, Experiment Station, State College Station, Fargo, N. D.
Mr. J. H. Shepperd	Chairman of Animal Husbandry Dept., Exper. Station, State College Station, Fargo, N. Dak.

BASIC IDEAS OF CONFERENCE

and

LETTER OF INVITATION

The following ideas received consideration in the planning of the Conference.

1. The breeding and production of varieties of wheat of high yields, of satisfactory quality, and possessing resistance to stem rust and to other diseases, is work to be done essentially by specialists in plant breeding as leaders, but their work can not be successful without strong aid and cooperation from workers in allied fields of science, as for example, the agronomist, the plant pathologist, the plant physiologist, the cytologist, and the chemist. Furthermore, a successful wheat breeding program must enlist the hearty cooperation and assistance of the practical farmer, the business man, and various educational forces.

2. The end in view in the production of new wheat varieties is economic in nature, but the method of procedure is highly technical and therefore the best scientific methods must be utilized for the sake of economy in time and money as well as for efficiency.

3. While marked improvement in wheat varieties is possible by the use of methods and knowledge now in vogue, any well-planned program must include within its scope scientific research in order to discover new facts about inheritance and other problems involved.

4. Further expansion or elaboration of present work in the improvement of existing wheat varieties is dependent upon increased funds and man power, and upon closer cooperation and organization of the forces now in action.

Letter of Invitation

Results during recent years have indicated marked possibilities in the way of modifying present hard spring wheat varieties for the development of resistance to black stem rust and to other diseases. It is believed better organization and coordination should be effected among the various men and institutions concerned in order to make the work more efficient and to hasten results. In order to formulate and lay out a program along the above lines, I am inviting you to a conference at ten o'clock, March 27, 1928, at the North Dakota Agricultural College, State College Station, Fargo, North Dakota.

ADDRESS OF WELCOME

Dr. John Lee Coulter

(President, North Dakota Agricultural College)

After formally welcoming the group to Fargo, Dr. Coulter said:

"I am very glad to note that all of the different groups of people interested in the hard spring wheat industry are represented--that is to say, we have here farmers, scientists, business men representing elevators and the milling industry, as well as those representing the railroads, the press, and business in general.

"It is unnecessary for me to call attention to the fact that the hard red spring wheat grown in our section of the world represents annually from 10 per cent to 20 per cent of the world's wheat crop and that this particular variety holds a place equal to and probably superior to the wheat crop grown in any other part of the world. Because of the tremendous importance of this industry, which is worth an average of more than half a billion dollars to the people of this northwest area this year, it is well worth while to come together to attempt to better coordinate our activities and to find ways and means of increasing the work which is being done in order to secure even greater results in the future than have been secured in the past.

"For many years it was thought that this crop could be grown continuously year after year on the same soil without danger of deterioration of either the soil or the wheat. Students of the subject, especially the scientific men, have long realized that this could not be continued. Possibly the average farmer also realized this but has waited hoping that leadership would point the way to a better system.

"Our representatives of the provinces and states and national governments in cooperation with other agencies have now well developed programs looking toward a vast development of the hard spring wheat industry. In some areas this must come in the form of high yields of wheat in rotation with other crops and with livestock in a highly diversified system of agriculture.

"One of the outstanding problems, however, is that of breeding strains of wheat resistant to or immune from rust and other diseases or pests, while at the same time retaining all other good characteristics. It is this problem which is to receive special consideration at this meeting."

SEEING ALL SIDES OF A COMPLEX PROBLEM

By Carleton R. Ball

(Senior Agronomist in Charge of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture)

We are met to consider a more comprehensive and cooperative attack on an important and complicated problem. Concretely stated, it is to produce better wheats.

As an introduction to program building it seems worth while to present some phases of the problem which center in the personnel interested in it. These are submitted under three heads:

(1) The end desired by each group concerned;

(2) Why they do not all see the problem alike; and

(3) Unity of scientific belief and purpose needed.

1. The End Desired by Each Group Concerned

In the following paragraphs are set forth the immediate viewpoint and desire of the farmer, the breeder, the pathologist, the extensionist (county agents, editors, etc.), the grain dealer, the miller, and the baker.

The Farmer: The man who grows the crop wants a consistently high yielding variety which will stand for harvest and be of such quality that he will not be penalized in price.

The Agronomist: The agronomist wants a variety of high yield and good quality, adapted to the climatic conditions and to harvesting methods which are or may be employed, resistant to all the prevalent physiologic forms of stem rust and the other major fungus diseases of wheat, with high content and quality of protein, and possessing the other characteristics required by the miller and baker.

The Pathologist: This contributor to the breeding program is interested primarily in the reaction of the variety to attack by fungus diseases. He ardently desires that it shall be a good variety, resistant to all the prevalent physiological forms of stem rust, leaf rust, rough-spored bunt, smooth-spored bunt, loose smut, and the various seedling blights and foot rots. His range of requirements is relatively narrow in its scope but of greater intensity in the pathological field than that of the agronomist.

The Extensionist: The extension agronomists, extension pathologists, agricultural editors, county agents, executives of cooperating commercial groups, and all other community or regional publicists, desire a variety which they can boost whole-heartedly without need for explanation now or fear of a comeback later.

The Grain Dealer: Under this title are grouped the local buyer, the elevator companies, commission men, and members of the grain exchanges. They desire a variety of consistently good performance under varying environments, which will serve to standardize quality and to stabilize the grain market from year to year. They further desire a variety which is readily identified in commerce and of such quality as to cause it to be sought after.

The Miller: The man who manufactures flour has much the same need as the grain dealer, i. e., a variety of consistent performance, assuring him a continuous supply of high grade smut-free wheat of uniform weight and texture, easily scoured, with large protein content, large flour yield, high quality and content of gluten, and splendid baking qualities.

The Baker: The man who manufactures flour into bakery products for the ultimate consumer desires a flour of continuously uniform quality, low ash content, great water absorption, large loaf volume, and good color and texture of crumb.

It may be thought that these separate requirements and desires of the different groups of workers concerned are one and the same. Apparently this is not wholly the case.

2. Why They Do Not All See the Problem Alike

The farmer wants bushels, ease and certainty of harvest, and price. He cares relatively little about any specific character or quality so long as the average performance and net return are good. Without further information he will not be interested in resistance to the several diseases except as one of these develops a destructive epidemic, as has been true of stem rust and stinking smut. He will be interested in quality only so far as it is reflected to him in the price. If protein figures in the price scale he will be interested in high protein but will not be concerned about crease dirt, or flour yield, or the ash content, color, or gluten quality of the flour.

The agronomist, who is looked to by the farmer, on the one hand, for a variety of high yield and good quality, and by the grain dealer, the miller, and the baker, on the other hand, for varieties having certain specific characteristics required by the trade, naturally must be deeply concerned about many definite characters in the proposed wheat quality. Besides general high yielding power and quality he is concerned with such specific characters and qualities as length of straw; strength of straw as shown by resistance to crinkling and lodging; resistance to shattering by hail, wind, or overripeness; relative time of maturity with relation to the occurrence of hot winds and diseases; general and specific resistance to disease-producing organisms and their prevalent physiologic forms; kernel characteristics with relation to holding of dirt, smut spores, etc.; kernel texture as influencing bushel weight and market grade; total protein content; gluten quality; percentage of flour extraction; and the various flour characters that go to make up milling and baking quality. This is the scope of agronomic interest in the new varieties. In actual practice some of these may be forgotten or neglected. In any case, some of them will not loom as largely important to the agronomist as they will to some one of the other groups concerned with the variety and its product. This the agronomist must remember if he is to render the greatest service.

The plant pathologist will be concerned primarily with the resistance of the variety to each specific disease organism which is of importance in the area and to the more abundantly prevalent of the physiologic forms of these organisms, so far as they have been isolated and identified. In this particular field he will naturally wish to go much further than the average plant breeder and may be inclined to insist on his viewpoint as against the more general viewpoint of the other. Frequently his tendency will be to forget the stress laid on certain points by the baker, the miller, the grain dealer, or even the farmer, and to magnify those points with which he is most familiar and the importance of which he is best able to judge.

<u>The extension workers and publicists</u> contact primarily with the farmer, and hence they want in general to provide what the farmer wants. Beyond that, however, they are educators and desire to awaken in the farmer an intelligent appreciation of what science can do for him. They encourage him, therefore, to want more things and to understand why he wants them. The extensionist contacts also with the commercial world and is somewhat sensitive to their specific viewpoints and desires. He is likely to be willing to agree with each in his specific requirement when it is demonstrated to him, but because of the multiplicity of his interests is not likely to get a clear view of the entire range of requirements unless he makes a special effort to do so.

<u>The grain dealer</u> wants uniform and continuous volume of business. He wants grain of quality but is little concerned with the method by which quality is assured. Whether chemical control, or breeding control, or some change in the method of production, he is in favor of it, if it tends to maintain quality. He likewise prefers relatively low price and active demand, even though the farmer is not so much profited by the production. On the other hand, he is more sensitive to the requirements of millers and bakers because his sales volume depends in part on his ability to supply what they want. As between the breeder, the pathologist, the farmer, and the extension worker he takes no sides. He may criticize the farmers for sowing weedy seed, or for growing mixed varieties, or grain of poor quality, and have little conception of the farmer's financial inability to avoid doing so. Likewise, he may criticize the breeder for not producing disease-resistant wheat, or the pathologist for not discovering a chemical method of control. He must be educated to appreciate the difficulties of each of the groups of scientific workers.

<u>The miller</u> is still further removed from the farmer, the breeder, and the pathologist than is the dealer. He is pleased with high quality and low price, rather than by high quality and high price, and, therefore, may not be naturally sympathetic with the farmers' desire to make good profits. He is displeased with mixed grain, weedy grain, smutty grain, and damaged grain. But he has little knowledge of the problems of the farmer who has to contend with the causes of these lowered qualities and has to suffer the financial losses they occasion. He is sensitive to his own problems of extra cleaning, extra tempering, and lowered extraction, which these conditions create, and may criticize farmer, scientist, and teacher alike in his disgust with their product when conditions have been unfavorable. He also must have sympathetic and constructive education.

The baker is at the end of the long list of wheat experts. He has to make the end product. This puts him between a very red hot devil and a very cold deep sea. On the one hand are the farmers, extension agents, agronomists, and pathologists, pushing along toward him some new wheat which he secretly fears, or openly avows, he does not want and can not use. On the other hand he dreads to hear the ungentle voice of Mrs. Vox Populi, telling the listening world that she never will buy any more of Blank's rolls or loaves, but will trade with his esteemed competitor henceforth and forever. To him a taint of garlic or smut may scent the bakeshop air more than would all the perfumes of Araby the Blest. To him .05 of one per cent of excess ash may loom larger than do all the problems of the farmer and dealer combined. The remedy is to invite him in to the breeding and testing game very near the start, so that any existing prejudice may be dispelled, or avoided, and the value of his viewpoint utilized.

3. Unity of Scientific Belief and Purpose Needed

There is the greatest need for a larger community of belief and purpose if this proposed program is to succeed. In the two previous sections of this paper there have been set forth (1) the ideal each group has before it, and (2) the reasons why the different groups do not see the ideal exactly alike. The different ideals prove to be a single ideal, seen simply from different angles. The emphasis laid by each group, however, on its own particular viewpoint may lead to divergent belief and action, each good in itself but harmful to the common cause.

In this third section is presented more particularly the need for substantial unity among the personnel of the scientific groups themselves. The agronomist and the pathologist need to be more than brothers in this proposed cooperative program, they need to be real Siamese twins, one and inseparable. This applies more especially to the agronomists and pathologists because there are more of them and because on them falls the larger part of the labor of this proposed program. It includes, however, the whole range of extensionists, comprising the college extension workers, the county agents, the editors of the farm and trade press, and the publicity men of the commercial groups. Nor can the commercial groups, the farmers, dealers, millers, or bakers, be left out of this requirement of friendly understanding.

A glance at the history of the human race shows us the ill effects of lack of unity. Movements, nations, and even civilizations have been jeopardized or destroyed because of splits or schisms among the people involved. Unity is seen to be the price of continued existence, not to mention effective results.

The Master Teacher Himself taught us that much of wisdom when He said: "Every kingdom divided against itself is brought to desolation; and every city or house divided against itself shall not stand" (Matt. 12:25). And in His last prayer for His disciples, just before His death, He prayed, not once but thrice, that they might be one in community of belief and deed (John 17:21-23).

Likewise Paul, in his first letter to the Corinthians, taught unity of need and purpose through the simile of the human body.

"The body is one, and hath many members, and all the members of that one body, being many, are one body (12:12). For the body is not one member but many" (12:14). "If the whole body were an eye, where were the hearing? If the whole were hearing, where were the smelling?" (12:17). "And the eye can not say unto the hand, I have no need of thee; nor again the head to the feet, I have no need of you" (12:21).

The causes for lack of unity may be (a) failing to get some of the facts; (b) prejudice (judging in advance of the evidence); or (c) differences in judgment as to the weight and value of certain facts.

The remedy lies in a friendly get-together, like the present conference. It lies in a desire and intent to get all the facts. It lies in a recognition of our prejudices and a conscious effort to keep our minds open to all the evidences that can be adduced. It lies in an earnest and intelligent willingness to recognize our individual limitations of knowledge and experience and to harmonize our judgments on the basis of the wisdom of the large majority. This is the spirit of democracy.

WHEAT BREEDING FOR YIELD, QUALITY, AND DISEASE RESISTANCE

By J. Allen Clark

(Agronomist in Charge, Western Wheat Investigations, Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture)

WHEAT IMPROVEMENT

The existence of different varieties of wheat has been recognized for more than 2,200 years. Theophrastus, writing about 300 B. C., stated that the "Many kinds of wheat grown take their names simply from the places where they grow." For centuries nature and man have been working together for improvement.

In the United States, introduction from foreign countries was the first method of obtaining better varieties. Selection from introduced and domestic sorts followed. Finally, hybridization is furnishing a more scientific method of originating new and improved varieties.

Outstanding examples of introduced varieties of wheat are Turkey and Kharkof (hard red winter), Baart and Federation (white), Arnautka and Kubanka (durum), and Red Fife (hard red spring). Important examples of improvement by selection are Kanred in Kansas, Trumbull in Ohio, Red Rock in Michigan, Kota and Nodak in North Dakota, and Mindum in Minnesota. The classical example of improvement by hybridization is Marquis. Others are Fulcaster, Triplet, Hybrid 128, Minturki and Ruby, all important varieties representative of the different classes of American wheat.

HISTORY OF WHEAT BREEDING FOR DISEASE RESISTANCE

Breeding for resistance in wheat to different diseases has been scientifically pursued since the rediscovery of Mendel's law in 1900.

FOREIGN

Biffen of England, in 1907, was the first to investigate the inheritance of resistance to the attacks of stripe rust, *Puccinia glumarum*. Nilsson-Ehle of Sweden, and Pole-Evans in South Africa, later confirmed the early results of Biffen showing that resistance was inherited as a recessive character.

Farrer of Australia, in 1901, was the first to attempt to bring about bunt resistance in wheats by hybridization. His work resulted in the development of two resistant varieties, Florence and Genoa. After Farrer's death in 1906, similar work was continued by Sutton. While Saunders of Canada did not give primary consideration to diseases in his wheat breeding, the resistance of Marquis to leaf rust and bunt are among the principal factors responsible for its wide adaptation and successful production.

AMERICAN

American wheat breeders working primarily for bunt resistance are Gaines in Washington, and Briggs in California. Mains in Indiana, Johnston in Kansas, and Leighty of the U. S. Department of Agriculture, are all breeding wheats resistant to leaf rust. Breeding for resistance to stem rust in the spring wheat area of the United States and Canada is engaging the attention of many Federal, State, Dominion, Provincial, and private workers, most of whom are here assembled.

OUR SPRING WHEAT AREA

While spring wheat is grown on approximately 20 million acres in 24 States, the principal acreage is in the four States, North Dakota, Montana, South Dakota, and Minnesota, their relative importance being in the order named. In these States nearly 17 million acres are grown, of which about 5 million acres, or 30 per cent, are in durum wheats. Of this 17 million acres, approximately 15 millions are subject to injury from black stem rust. An equal area, subject to similar losses, extends northward in Canada.

SUCCESSION OF VARIETIES HAS BEEN THE RULE

The commercial growing of the so-called Bluestem and Fife varieties was coincident with the settlement of the northern spring-wheat area of the United States, from 1875 to 1900. By 1896, Russian immigrants had introduced Arnautka durum, and in 1899 the United States Department of Agriculture introduced Kubanka and other durum varieties. Durum wheat became popular with growers because of its resistance to stem rust and drought. That rust has been the principal factor for the increase in durum is indicated by the gradual northward, rather than westward, movement of its centre of production. The rust resistance of Arnautka and Kubanka was commonly recognized, in comparison with the previously grown Red Fife and Haynes Bluestem varieties and later with Preston or "Velvet Chaff," which became commercially grown about 1905. In 1912, Marquis was introduced from Canada and soon became popular because of its earliness and presumed ability to escape rust. After the severe stem rust epidemic of 1916 three resistant durum varieties, Pentad (D-5), Monad (D-1), and Acme, increased in acreage. The rust resistance of Kota was discovered in 1918 and it became commercially grown by 1922. At least 1,500,000 acres of these rust-resistant varieties are now grown.

Other varieties have come and many of them have gone, due to their low yield, poor quality, or susceptibility to disease.

IMPROVEMENT OF VARIETIES

The scale for weighing the fitness of a new variety to compete with the old has been its comparative yield and quality as determined from varietal experiments conducted at our publicly supported State and Federal agricultural experiment stations. In the four principal spring-wheat States there are 24 such stations, representative of different grain-producing sections. Varietal experiments at some of these stations have been continuous from their establishment, while at others they have been abandoned and resumed as financial support has fluctuated.

These experiments have been fundamental to the development and prosperity of our spring wheat area. The original investment in these experiment stations represented fully a million dollars, and their present worth is now much more than that. We all are responsible for paying dividends on this investment. Their most efficient use, therefore, should be our joint duty. They have paid good dividends in the past. Can they be made to pay larger dividends in the future?

Service to an area of 20 million of acres having an average acre yield of but 12.5 bushels and a production of 250 million bushels, is our challenge. An increase in yield of one per cent would represent 2.5 million bushels or 100 per cent dividends on the present value of the public investment in stations and personnel.

Yield and Quality

The varietal experiments conducted at 12 stations in North Dakota and South Dakota during the past 25 years have shown that Kubanka durum has outyielded the original Bluestem and Fife varieties by 40 and 30 per cent, respectively. The experiments show that Kubanka has outyielded Preston or "Velvet Chaff" by 25 per cent. Since 1916, Marquis has been the principal hard red spring wheat and Kubanka has outyielded it in the Dakotas by about 15 per cent. Kubanka has outyielded the more recently developed Kota by about 10 per cent, while Kota in turn has outyielded Marquis by about 5 per cent.

Varietal improvement has not been confined to yield. Improvement in the quality of new productions also has been made, although this is harder to obtain and measure. The improved quality of Marquis over that of varieties previously grown, however, is beyond question.

Continued improvement in both yield and quality has been indicated in recent experiments with new varieties bred for rust resistance. With the discovery of resistance to black stem rust in the common wheats, Kota and Kanred, the problem of breeding for rust resistance appeared to be much more simple than was formerly the case, when it had been necessary to obtain resistance through species or subspecies hybrids between durum and hard red spring varieties. Much of the early work was done in Minnesota, using the Iumillo durum, which is very resistant. The popularity and commercial importance of Marquis made it the logical variety for crossing to combine high yield and quality with resistance.

New Varieties

Hybrids between Iumillo and Marquis produced in cooperative experiments at the Minnesota station resulted in the Marquillo variety. So far, the only named spring variety resulting from crosses between Kanred and Marquis is Reliance. From the crosses of Kota and Marquis the Ceres variety has been developed by the North Dakota station. These three varieties have been advanced from nursery to plot experiments and have been tested at some of the experiment stations during some of the years since 1923.

Among durum wheats, crossing has not yet resulted in the production of a new variety. The Mindum and Nodak varieties, developed by selection, are the most promising for the rust area.

The annual and average yields of Ceres, Marquillo, Reliance, Mindum, and Nodak since 1923, in plot experiments in comparison with the standard Marquis and Kubanka varieties at 22 experiment stations in six States, are shown in Table 1. The average yields of other varieties, when the comparable tests were with those of Marquis at each station and in each State, are given in percentage of Marquis.

Table 1. Annual and average yields obtained from Marquis, Ceres, Marquillo, Reliance, Mindum, Kubanka, and Nodak spring wheats grown in replicated plats at experiment stations in Minnesota, North Dakota, South Dakota, Nebraska, Wyoming, and Montana, in some or all of the years from 1923 to 1927, inclusive

State and Station	Year	Yield, Bushels per Acre						
		Hard Red Spring				Durum		
		Marquis	Ceres	Marquillo	Reliance	Mindum	Kubanka	Nodak
MINNESOTA								
St. Paul	1923	19.5				16.6		
	1924	33.3		32.0		24.9		
	1925	29.2	34.1	31.4	31.5	36.2		
	1926	16.3	19.5	12.1	16.8	15.9		
	1927	19.8	31.8	31.7	20.5	37.6		
Average - bushels		23.6				26.2		
Percentage of Marquis		100.0	130.7	108.5	105.0	111.0		
Crookston	1923	13.5				17.2		
	1924	20.5		30.0		35.6		
	1925	27.9	33.7	37.7		40.2		
	1926	25.4	31.6	35.0		35.4		
	1927	19.5	23.6	26.8	15.6	26.2		
Average - bushels		21.4				30.9		
Percentage of Marquis		100.0	121.8	140.3	80.0	144.4		
Morris	1923	23.6				31.3		
	1924	28.9		27.9		28.3		
	1925	17.6	16.4	20.6	9.4	31.6		
	1926	19.6	17.4	17.2	18.1	18.1		
	1927	17.7	23.9	30.9	15.8	31.8		
Average - bushels		21.5				28.2		
Percentage of Marquis		100.0	104.9	115.2	78.7	131.2		
Waseca	1923	21.6				25.2		
	1924	37.2		42.1		35.1		
	1925	24.6	24.9	23.3	18.6	24.8		
	1926	16.5	18.6	13.0	19.0	30.5		
	1927	17.9	23.2	22.4	13.3	27.8		
Average - bushels		23.6				28.7		
Percentage of Marquis		100.0	112.7	104.6	86.3	121.6		
Grand Rapids	1923	10.5				11.2		
	1924	15.0		15.4		13.9		
	1925	19.2	24.3	21.3		18.4		
	1926	25.3	28.8	35.8		25.8		
	1927	18.6	19.0	21.2		25.8		
Average - bushels		17.7				19.0		
Percentage of Marquis		100.0	114.3	120.0		107.3		
STATE AVERAGE - bushels		21.5				26.6		
Percentage of Marquis		100.0	117.6	117.3	89.9	123.7		

Table 1. (Continued)

State and Station	Year	Hard Red Spring: Marquis	Hard Red Spring: Ceres	Hard Red Spring: Marquillo	Hard Red Spring: Reliance	Durum: Mindum	Durum: Kubanka	Durum: Nodak
		Yield, Bushels per Acre						
NORTH DAKOTA								
Fargo	1923	25.5	32.2			33.0	27.8	30.7
	1924	39.5	45.3			43.3	39.1	39.4
	1925	23.9	29.3	27.8	19.0	35.0	31.6	28.5
	1926	18.2	24.2	21.9	24.6	35.3	29.4	31.6
	1927	26.2	30.6	26.1	24.7	34.2	29.3	27.4
Average - bushels		26.7	32.3			36.2	31.4	31.5
Percentage of Marquis		100.0	121.0	111.0	100.0	135.6	117.6	118.0
Mandan	1923	12.9				14.2	14.2	14.4
	1924	25.4	27.8		25.6	21.5	23.7	24.9
	1925	15.2	15.4	14.2	16.0	19.2	17.4	18.4
	1926	2.9	3.0	2.7	3.2	2.1	2.6	3.3
	1927	15.4	18.6	15.1	16.6	19.6	21.5	21.0
Average - bushels		14.4				15.3	15.9	16.4
Percentage of Marquis		100.0	110.2	95.5	104.8	106.3	110.4	113.9
Dickinson	1923	18.3	20.9			21.3	22.9	23.8
	1924	23.3	26.7		23.9	18.5	20.0	21.0
	1925	17.4	20.1	14.9	20.1	14.1	14.5	15.5
	1926	6.2	7.4	6.2	5.8	4.8	5.7	6.3
	1927	18.2	24.2	17.4	19.5	24.3	24.2	24.0
Average - bushels		16.7	19.9			16.6	17.5	18.1
Percentage of Marquis		100.0	119.2	92.1	106.1	99.4	104.8	108.4
Williston	1924	39.8	45.3				34.5	31.3
	1927	29.2	34.3			28.9	30.7	27.6
Average - bushels		34.5	39.8				32.6	29.5
Percentage of Marquis		100.0	115.4			99.0	94.5	85.5
Langdon	1925	11.2	12.1				14.2	
	1926	19.5	24.2				25.4	
	1927	26.1	30.1	35.6		33.6	30.1	32.5
Average - bushels		25.2	29.2				27.0	
Percentage of Marquis		100.0	115.9	136.4		128.7	107.1	124.5
Edgeley	1925	18.2	30.5					
	1927	18.9	25.3	23.4		18.7	21.5	19.3
Average - bushels		18.6	27.9					
Percentage of Marquis		100.0	150.0	123.8		98.9	113.8	102.1
STATE AVERAGE - bushels		20.5						
Percentage of Marquis		100.0	120.1	108.7	103.4	112.5	110.6	109.4
SOUTH DAKOTA								
Redfield	1923	17.2					21.3	
	1924	40.4					32.7	
	1925	12.0	19.3	17.9	10.3		18.9	24.0
	1926	6.3	9.7	3.1	4.8		8.6	7.4
	1927	30.4	35.1	29.9	31.1		33.0	37.3
Average - bushels		21.3					22.9	
Percentage of Marquis		100.0	132.1	104.9	95.1		107.5	141.4

Table 1. (Continued)

State and Station	Year	Hard Red Spring: Marquis	Ceres	Marquillo	Reliance	Durum: Mindum	Kubanka	Nodak
		Yield, Bushels per Acre						
SOUTH DAKOTA Cont'd								
Brookings	1923	4.2				7.5	7.5	
	1924	27.1				20.9	21.7	21.3
	1925	13.0	22.5			42.1	34.2	37.6
	1926	14.2	20.5			20.8	17.9	22.9
	1927	26.7	23.0			19.2	20.9	35.7
Average - bushels		17.0				22.1	20.4	
Percentage of Marquis		100.0	122.2			130.0	120.0	144.8
Highmore	1923	9.6				24.2	22.8	
	1924	28.6				22.1	21.5	
	1925	12.5	16.9			17.5	17.9	16.9
	1926	0.0	0.0			0.0	0.0	0.0
	1927	31.4	34.1			30.9	30.9	30.9
Average - bushels		16.4				18.9	18.6	
Percentage of Marquis		100.0	116.4			115.2	113.4	108.9
Eureka	1927	23.5	35.3			42.1	34.1	43.6
Percentage of Marquis		100.0	150.2			179.1	145.1	185.5
Ardmore	1923	25.0					24.4	
	1924	1.7					4.7	
	1925	22.7					18.3	
	1926	8.5	6.5		7.0		11.2	8.5
	1927	38.2	39.2		38.6		40.0	47.0
Average - bushels		19.2					19.7	
Percentage of Marquis		100.0	102.2		102.2		102.6	119.3
STATE AVERAGE - bushels		18.7					21.1	
Percentage of Marquis		100.0	121.0	104.9	96.3	130.1	112.8	136.2
NEBRASKA								
Lincoln	1923	18.5					18.1	
	1924	10.9					13.0	
	1925	3.7					4.3	
	1926	1.1					1.6	
	1927	10.8	15.0				12.1	
Average - bushels		9.0					9.8	
Percentage of Marquis		100.0	138.9				108.9	
North Platte	1924	13.6					14.5	13.5
	1925	15.8	15.3	11.5	14.7		15.3	16.0
	1926	2.7	2.9	1.5	1.5		1.8	2.2
	1927	21.8	23.3	21.3	22.6		21.3	21.5
Average - bushels		13.5					13.2	13.3
Percentage of Marquis		100.0	103.0	85.1	96.3		97.8	98.5
STATE AVERAGE - bushels		11.0					11.3	
Percentage of Marquis		100.0	110.1	85.1	96.3		102.7	98.5

Table 1. (Continued)

State and Station	Year	Yield, Bushels per Acre: Hard Red Spring: Marquis	Ceres	Marquillo	Reliance	Durum: Mindum	Kubanka	Nodak
WYOMING								
Cheyenne	1923	1.9					10.9	
	1924	6.9					11.7	12.3
	1925	7.9	9.6				9.4	8.7
	1926	13.8	15.5				18.3	17.0
	1927	18.9	22.9				24.4	27.3
Average - bushels		9.9					14.9	
Percentage of Marquis		100.0	118.5				150.5	137.0
Sheridan	1923	25.3					26.7	26.2
	1924	38.5					32.7	32.0
	1925	38.4	47.3		42.2		38.9	36.7
	1926	29.3	34.7		32.0		31.3	30.4
	1927	43.3	48.0		43.3		44.0	44.2
Average - bushels		35.0					34.7	33.9
Percentage of Marquis		100.0	117.0		105.9		99.1	96.9
STATE AVERAGE - bushels		22.4					24.8	
Percentage of Marquis		100.0	117.4		105.9		110.7	105.2
MONTANA								
Bozeman	1925	53.7			63.3			
	1926	34.7			31.2			
	1927	68.3			70.7			
Average - bushels		52.2			55.1			
Percentage of Marquis		100.0			105.6			
Moccasin	1923	24.6					25.6	25.7
	1924	32.0		31.5	31.1		27.7	23.2
	1925	22.4	25.6	23.3	24.3		21.2	22.8
	1926	30.0	30.7	29.1	32.6		28.4	29.3
	1927	18.2	22.2		22.2		20.9	19.6
Average - bushels		25.4					24.8	24.1
Percentage of Marquis		100.0	111.5	99.6	107.4		97.6	94.9
Havre	1923	20.3					20.0	18.3
	1924	12.3					9.0	11.1
	1925	16.4	18.1		17.2		17.5	18.9
	1926	2.8	3.6		3.9		5.0	5.3
	1927	36.8	37.1		40.6		40.6	40.6
Average - bushels		17.7					18.4	18.8
Percentage of Marquis		100.0	104.8		110.2		104.0	106.2
STATE AVERAGE - bushels		28.7						
Percentage of Marquis		100.0	108.5	99.6	107.0		100.0	99.5
ALL STATION AVERAGE								
Station years		100	64	40	42	54	71	55
Variety		20.8	23.9	22.6	22.9	24.7	21.0	23.2
Marquis same years		20.8	20.3	20.3	22.7	20.2	19.2	20.7
Percentage of Marquis		100.0	117.7	111.3	100.9	122.3	109.4	112.1

The table shows that as new varieties have been developed they have not been uniformly tested at all available State and Federal experiment stations in the spring wheat area. They usually are tested at all stations within the State where developed. For instance, the Marquillo and Mindum varieties have been tested principally at stations in Minnesota, in which State they were developed. The Ceres and Nodak varieties, developed in North Dakota, have been tested principally in that State. That these varieties, and Reliance, have been tested at stations in several other States has been due largely to official and unofficial cooperation between Federal and State agencies. The blanks in the table indicate need for more and better cooperation in such tests.

The data for Minnesota show Mindum to be the best yielding variety, outyielding Marquis at all stations, and by 23.7 per cent on the average for the State. However, Minnesota produces very little durum, Marquis being the principal variety grown. Of the new hard spring varieties, Marquillo and Ceres have outyielded Marquis by more than 17 per cent. In 15 comparisons in Minnesota, Marquillo outyielded Ceres by 0.7 bushel or 2.8 per cent.

In North Dakota, in experiments at six stations, Kubanka outyielded Marquis at all stations except Williston, and by 10.6 per cent on the average for the State. Mindum outyielded Kubanka and Nodak at the Fargo and Langdon stations, which are in the eastern Part of the State. At the Mandan and Dickinson stations in the central and western part of the State, respectively, Nodak is the highest yielding durum and Mindum yielded less than Kubanka. Of the hard red spring wheats, Ceres has outyielded Marquillo and Reliance and the leading durum varieties by approximately 10 per cent. This shows marked improvement. On the average for the State, Marquillo outyielded Marquis by 8.7 per cent and Reliance outyielded Marquis by 3.4 per cent.

In South Dakota, Nodak durum has outyielded both Kubanka and Mindum. Among the hard red spring wheats Ceres has significantly outyielded Marquis as well as Marquillo, Reliance, and even Kubanka.

In Montana, durum wheats have not outyielded hard red spring wheats. Under rust-free conditions in Montana, Marquis is a very high-yielding wheat, but is outyielded by both Ceres and Reliance, which also yield slightly more than Supreme, an awnless variety, which is becoming popular in that State. In 6 comparisons in Montana, Reliance outyielded Ceres by 0.6 bushel or 2.5 per cent.

The average results from the four States show that Ceres is the most widely adapted new hard red spring variety, exceeding Marquis in average yield for the whole area by 17.7 per cent.

Table 2. Summary of milling and baking data from 23 samples of Ceres wheat, and from 22 of these Ceres samples and 22 comparable samples of Marquis, grown in one or more of the 4 years from 1923-1926, inclusive

Descriptive data	All Ceres samples	Comparable samples: Ceres	Comparable samples: Marquis	Comparable samples: Percentage of Marquis
Number of samples	23	22	22	
Bushel weight:				
Mill cleaned .... pounds	60.2	60.1	58.7	102.4
Crude protein content of wheat	14.7	14.7	14.3	102.8
(Nx15.7, basis 13.5 p.c. moisture) p.c.				
Yield of straight flour .... do	75.3	75.2	72.6	103.6
Yield of shorts .... do	12.6	12.7	13.2	96.2
Yield of bran .... do	13.5	13.6	15.8	86.1
Water absorption of flour ...... do	64.6	64.7	60.6	106.8
Volume of loaf ......cubic centimeters	2,205	2,211	2,154	102.6
Weight of loaf .... grams	504	504	508	99.2
Texture of crumb .... p.c.	91.2	91.2	91.0	100.2
Color of crumb .... do	89.3	89.2	89.1	100.1
Ash in flour .... do	.51	.51	.51	100.0

This increased yield obtained from Ceres also has been accompanied by an increase in quality, as indicated by the results of milling and baking experiments shown in Table 2. The average data from 22 comparable samples, covering a period of 4 years, show Ceres to exceed or equal Marquis in test weight per bushel, crude protein content, flour yield, water absorption, volume of loaf, and texture and color of crumb. Similar improvement has been made by other new varieties. This illustrates the opportunity for improvement of quality as well as yield.

PRODUCTION LIMITED BY DISEASE AND DROUGHT

The wheat diseases, including stem rust, leaf rust, stinking smut, loose smut, scab, foot rot, and black chaff, together with drought, are the principal factors limiting production. Most of these factors also reduce the weight and quality of the grain.

RUST PREVALENCE AND REACTION OF VARIETIES

Some stem rust infection has occurred in the Dakotas and Minnesota during at least the past 12 consecutive years. In some years the rust has been very destructive. In Table 3 are presented the annual and average percentages of stem rust on Marquis wheat at 18 stations in the three States during one or more of the 9 years from 1919 to 1927, inclusive. These percentages represent the infection present, at harvest time, according to a certain scale.

The data do not show very important differences between the States, the infection on Marquis in Minnesota averaging 56, in South Dakota 55, and in North Dakota 49 per cent, for the 9 years. The stations having the most rust are Crookston and Morris, Minn., Brookings and Webster, S. Dak., and Fargo, Edgeley, and Langdon, N. Dak. The year 1927 shows the highest average infection for the three States, or 68 per cent.

With these data as a basis, other varieties grown in the uniform rust nurseries are compared with each other, and ranked in comparison with Marquis taken as 100 per cent. These data are given in Table 4. The most resistant variety is Vernal emmer, which had but 0.1 per cent of stem rust infection, on the average. Preston, a hard red spring, had the highest average infection, 57.6 per cent. The three most resistant durum varieties, Pentad, Monad, and Acme, all showed an average of less than 3 per cent of rust and Nodak had but 5.5 per cent. Kota averaged less than 12 per cent infection or 22.4 per cent of the infection on Marquis. Selection 1656.81 from the cross of Kota by Marquis has much greater resistance than Kota, averaging but 6.7 per cent of infection in two years. Hope wheat has more resistance than Kota, Kota-Marquis hybrids, or even the most resistant durums. Like the emmers, Hope is practically immune in the field from any of the physiologic forms of stem rust which occur in the spring wheat area. In 29 nursery trials in two years Hope has averaged but 0.3 per cent of rust, where Marquis, under similar conditions, rusted 55 per cent. This is only 0.6 per cent of the infection on Marquis.

Table 3. Annual and average percentage of stem-rust infection of Marquis wheat in 104 nursery years at 18 stations in North Dakota, South Dakota, and Montana, during one or more of the 9 years from 1919 to 1927, inclusive

State and Station	1919	1920	1921	1922	1923	1924	1925	1926	1927	Average
North Dakota:										
Fargo	100	65	90	98	70	65	95	80	40	78
Langdon			25	40	85	55	80	70	75	61
Edgeley			85	45	80	10	95	8	85	58
Mandan	25	65	8	40	30	25	50	0	70	35
Dickinson	0	16	5	55	20	25	1	T	35	17
State average	42	49	43	56	57	36	64	32	61	49
South Dakota:										
Brookings	85		50	65	70	70	75	35	65	64
Redfield				80	50	T	85		40	51
Webster									95	95
Highmore	70	25					35		25	39
Newell	50						10	40	80	45
State average	68	25	50	73	60	35	51	38	61	55
Minnesota:										
St. Paul	40		T	50	35	T		25	85	34
Crookston			90	90	40	95	70		75	77
Morris			40	30	90		90		95	69
Golden Valley			10							10
Duluth			55	80	80	20	45	60	95	62
Waseca				95	35	60	75	50	35	58
Coon Creek				25	60		63	40	95	57
Red Wing								12	70	42
State Average	40		39	62	57	44	69	37	79	56
Average three States	53	43	42	61	58	39	62	35	68	53.2

Table 4. Average annual percentage of stem-rust infection of the more important varieties of emmer and wheat grown in uniform rust nurseries at 18 stations in North Dakota, South Dakota, and Minnesota, together with a comparison with Marquis, during two or more of the nine years from 1919 to 1927, inclusive

Class and Variety	C.I. No.	Stem-rust infection (per cent) 1919	1920	1921	1922	1923	1924	1925	1926	1927	Weighted average	Marquis same yrs.	Nursery years	Percentage of Marquis
Emmer:														
Vernal	3686	T	0	T	T	0	0	0	0	T	0.1	53.2	104	0.2
Khapli	4013	T	0	0	0	T	0	T	0	T	0.2	52.7	100	0.4
Durum:														
Pentad	3322	1	T	3	6	2	T	T	2	1	1.7	53.2	104	3.2
Monad	3320	4	2	3	5	2	1	1	1	2	2.3	52.9	103	4.3
Acme	5284	6	4	4	4	2	0	2	1	3	2.8	52.9	103	5.3
Nodak	6519						5	3	3	10	5.5	53.4	55	10.3
Kubanka	1440	13	11	21	41	22	8	13	7	24	18.6	53.6	100	34.7
Arnautka	1493			26	43	25	8	10	5	24	19.8	54.3	90	36.5
Mindum	5296	18	13	19	37	25	9	9	5	32	19.8	53.2	104	37.2
Hard Red Spring:														
Hope	8178								T	T	.3	54.5	29	0.6
Kota x Marquis 1656.81	8185								3	10	6.7	54.5	29	12.3
Kota	5878	3	4	3	10	17	11	16	6	22	11.9	53.2	104	22.4
Ceres	6900							19	5	28	18.8	57.1	44	32.9
Marquillo	6887						15	21	6	30	19.3	53.4	55	36.1
Ruby	6047	38	25	24	51	51	35	49	20	50	40.4	53.0	102	76.2
Reliance	7370						26	58	23	60	44.4	53.4	55	83.1
Marquis	3641	53	43	42	61	58	39	62	35	68	53.2		104	100.0
Haynes Bluestem	2874	61	61	44	70	64	41	56	36	56	54.2	53.2	104	101.9
Power	3697	62	51	43	72	67	40	65	39	64	57.2	53.6	100	106.7
Preston	3081	64	59	45	68	68	43	71	34	62	57.6	53.2	104	108.3
White:														
Quality	6607						25	42	23	48	36.5	53.4	55	68.4
Little Club	4066			43	70	64	55	67	42	44	55.4	53.4	91	103.7

EARLINESS NOT SUCCESSFUL IN PERMITTING RUST ESCAPEMENT

The earliness of Marquis, which made it popular because it apparently escaped rust during the first few years of its production, has not proved to be an important rust control factor. Marquis shows practically as much stem rust as later-maturing varieties, such as Haynes Bluestem, Power, and Preston. Other early varieties, such as Prelude, Ruby, and Quality, commercially grown in the spring-wheat States have not successfully escaped rust, and earliness has been accompanied with a sacrifice in yield. The development and growing of early varieties, therefore, has not been a successful method of rust control.

BREEDING FOR STEM-RUST CONTROL

In the field, varieties or hybrids may be classified genetically for reaction to stem rust as susceptible, resistant, and immune. Resistance is inherited as a recessive character and immunity as a dominant character. Most varieties of wheat are susceptible to black stem rust. For many years certain durum varieties have been recognized as resistant to the disease. In recent years several resistant hard red spring varieties have been discovered or bred. Until the production of Hope wheat, only certain varieties of emmer could be classed as practically immune. In each of these groups there is variability and over-lapping, due to seasonal conditions and plant development, as well as to the prevalence of the disease and the particular physiologic forms of stem rust present.

Susceptibility or resistance of seedlings in the greenhouse is not necessarily an indication of field reaction. Kanred and crosses from it in such tests have shown immunity from certain physiologic forms, the immunity from eight or more forms being inherited as a single genetic factor. The immunity of Kanred from attack by these forms in the greenhouse has not been followed by similar resistance when Kanred is grown in the field in the spring-wheat area. This is true also of the Kanred-Marquis hybrid, Reliance. Likewise greenhouse tests showing susceptibility in the seedling stage of Kota x Marquis hybrids and crosses between durums have been followed by resistance in the fruiting stage when these hybrids were grown in the field.

Breeding for Resistance in the Past

The breeding work of the past has been for stem-rust resistance. In the United States part of this work has been cooperative between the Office of Cereal Crops and Diseases and the Minnesota and North Dakota stations. The breeding has been conducted at University Farm, St. Paul, Minn., and at the Fargo, Mandan, and Dickinson stations in North Dakota, and privately by Mr. McFadden on his farm near Webster, S. Dak.

In the breeding nursery at University Farm, St. Paul, infection with stem rust is artificially produced through spraying the nursery with rust spores of numerous physiologic forms collected in the spring wheat area. In North Dakota, this has not been done, but there usually has been ample field infection. In addition to the rust nursery at St. Paul, there recently has been developed a disease garden at that place where all plant diseases, including rust, smut, scab, mildew, and black chaff, are introduced. All new strains are to be tested in this garden for resistance to all these diseases.

The most outstanding new productions are Dr. Waldron's recent selections from the Kota x Marquis cross, viz., 1656.85, 1656.84, and 1656.81, which have proved to be very high-yielding strains at experiment stations and in cooperative farm nurseries established with the Smith-Hughes men throughout North Dakota, during the past year. The yields obtained from these strains, and from Hope, Marquillo, Ceres, and Marquis, are compared in Table 5.

Selection 1656.85, the most outstanding one, and Hope, have not yet been tested in plot experiments. These preliminary nursery experiments indicate a possible improvement in yield of 57.8 and 30.5 per cent for these varieties, respectively, as compared with Marquis. In early experiments Haynes Bluestem, the principal variety grown 20 years ago, yielded about 40 per cent less than Marquis. These recent experiments show 1656.85 to yield 58 per cent more than Marquis. This approaches 100 per cent improvement in yield and illustrates the possibilities of improvement in the future.

Large numbers of even more promising selections from crosses now are becoming available for testing at the breeding stations; in fact, more than can be adequately handled at the present stations, with the funds available. For durum wheats we have no breeding station representative of the durum area.

Table 5. Yield in bushels per acre obtained from Marquis, Ceres, the Kota x Marquis selections 1656.85, 1656.84, and 1656.81, Marquillo, and Hope wheats in plat and nursery experiments in North Dakota in 1927

Experiment and Station in N.Dak.	Yields in bushels per acre						
	Marquis	Ceres	1656.85	1656.84	1656.81	Marquillo	Hope
EXPERIMENT STATIONS							
Plat							
Fargo	26.2	30.6		34.1	30.8	26.1	
Edgeley	18.9	25.3		30.3		23.4	
Langdon	26.1	30.1		30.3		35.6	
Mandan	15.4	18.6		19.7		15.1	
Dickinson	18.2	24.2		24.2		17.4	
Williston	29.2	34.3		31.5			
Nursery							
Fargo	34.7	33.3	39.2	40.6	40.4	34.7	35.0
Edgeley	20.0	30.0	46.1	39.1	40.8	23.0	39.7
Langdon	26.9	28.6		31.8	32.5	31.1	32.5
Mandan	22.5	30.8		33.3	33.1	24.5	29.2
Dickinson	16.0	22.6		25.4	21.2	17.2	16.2
FARM COOPERATORS							
Nursery							
Arthur	17.3	25.9	44.1	35.2	31.7	27.8	
LaMoure	22.4	27.8	34.7	31.0	31.5	21.0	
Ellendale	18.2	30.2	48.2	36.5	41.5	27.7	39.5
Valley City	29.0	45.4	55.4	52.9	54.1	41.2	37.7
Milnor	19.2	18.7	20.3	18.9	17.3	14.9	13.4
Buffalo	13.7	16.5	21.2	19.6	20.7	12.4	
Grafton	42.0	50.7	58.6	51.0	45.6	43.9	
Park River	33.5	35.1	45.5	42.8	41.8	36.7	
Neche	20.9	31.1	37.2	30.5	32.3	30.1	
Velva	19.7	25.1	26.2	25.9			
Granville	10.7	11.0	8.0	8.4			
Kenmare	18.7	21.4	22.5	24.1			
Hazen	14.2	16.8	23.6	21.7			
New Salem	15.1	18.6	19.3	19.8			
New England	18.5	22.4		24.3			
Beach	32.3	42.7		38.1			
AVERAGES — No. trials							
Bushels — 27	22.2	27.7		30.4			
16	21.8	27.4	34.4	31.1			
15	24.2	30.5		34.8	34.4	27.5	
19	23.2	29.2		33.0		26.5	
8	23.3	30.0		34.8	35.1	26.8	30.4
Percentages — 27	100.0	124.8		136.9			
16	100.0	125.7	157.8	142.7			
15	100.0	126.0		143.8	142.1	113.6	
19	100.0	125.9		142.2		114.2	
8	100.0	128.8		149.4	150.6	115.0	130.5

Breeding for Immunity in the Future

The Hope variety, bred by Mr. McFadden from a cross of Yaroslav emmer and Marquis wheat has the practical immunity of the emmer parent. No rust form yet encountered readily attacks emmer in the field, where it has been grown for nearly 50 years. Data so far obtained indicate that similar results may be confidently expected from Hope wheat and hybrid selections from it. The production of Hope wheat is the most encouraging development in recent years, and has given a great impetus to breeding as a method of controlling black stem rust and other diseases in the spring-wheat States. The practical immunity of Hope wheat should simplify the situation so far as physiologic forms are concerned in their effect on the breeding program.

Most of the breeding for rust control in the immediate future will center on Hope wheat in order to try and fix its practical immunity in more valuable varieties. Already there is much material available from crosses with Hope or related strains. Partly through the use of greenhouse facilities and the growing of two generations a year, there will be available for sowing in 1928 some F_5, F_4, F_3 or F_2 material of crosses between Hope and Reliance, Ceres, Marquillo, Marquis, Supreme, and the selections 1656.81 and 1656.84. From these crosses strains practically immune from or highly resistant to both stem rust and leaf rust and to bunt and loose smut, soon may be obtained. The important problem confronting us is to provide facilities for testing large numbers of selections of new crosses for reaction to disease organisms and for yield and quality.

AN ADEQUATE PROGRAM

The new resistant or practically immune varieties should be more carefully and extensively tested than has been possible in the past. The present situation justifies the expanding of our cooperation between State and Federal agencies to make the best use of every available experiment station located in the spring-wheat area.

In the case of Ceres, an outstanding new variety, there are but 64 comparable plot trials of it and Marquis at experiment stations since 1923, whereas 130 comparisons could have been made if all available stations had been used. In this instance the stations have been used to only 50 per cent of their potential efficiency. In the testing of other new varieties the stations have been used to not more than 40 per cent of their possible efficiency.

BREEDING STATIONS

Additional breeding stations also should be developed in the heart of the area producing both hard red spring and durum wheats. Results in the past have shown definitely that it is not satisfactory to try and breed wheats at a station outside of the area where the new productions are intended to be commercially grown. Without establishing new stations for breeding purposes, the additional work could be done with confidence at Redfield, S. Dak., and at Langdon, N. Dak., stations which are in the heart of the durum area and also in the hard red spring area. Redfield, in the southern part of the durum area, is located in the James River Valley, which is a broad fertile wheat-growing valley. The Langdon, N. Dak., substation, located in the northern part of the durum area, is probably more typical of the present and future durum wheat area than any other station, as the durum acreage is moving northward.

Durum wheat millers and macaroni manufacturers recognize the fact that durum wheat grown outside of the principal durum wheat territory does not have the desirable appearance of the grain and color of the product shown by the wheat grown within this territory. Improvement must soon be made with durum wheats or the industry will suffer. The best varieties are not sufficiently resistant to rust and the resistant varieties do not have high quality for the manufacture of semolina and its products. The improvement made in the yield of such resistant hard red spring wheats as Ceres, Marquillo, Hope, and other unnamed hybrid selections, may soon result in a reduction of the acreage of durum or the price of durum must increase and remain above that of hard red spring.

TESTING STATIONS

There are at least 20 experiment stations in the 4 spring-wheat States here represented which should have varietal experiments in plots. They are fairly representative of the spring wheat area. With greater cooperation and financial support new varieties and strains could be tested both for yield and quality much more uniformly and extensively than is now possible.

Quality Determinations

To insure the production of varieties of high quality, crude protein determinations on common wheats and gasoline color tests on durum wheats should furnish a basis for selection in the nurseries at breeding stations. Milling and baking tests and semolina and macaroni trials, made on samples from the plot experiments at all testing stations, should furnish reliable information as to quality, particularly if the method of making these trials is uniform. Provision for this could be made by cooperation with the State stations and with the Milling Investigations Laboratory of the U. S. Bureau of Agricultural Economics. Equipment would have to be provided for experimental macaroni manufacture from the durum wheats.

COOPERATIVE FARM NURSERIES

In addition to more breeding and testing stations, there should be inaugurated uniform cooperative farm nurseries in each of these four spring-wheat States. Such cooperative tests with county agents, Smith-Hughes teachers, and farmers, have become very popular both for demonstration and experimental purposes in some States in recent years. They furnish more extensive data than can be obtained in any other way, and the nurseries form a contact between the experiment station, extension workers, and farmers which appears necessary in order to put over most successfully a crop improvement and standardization program.

AN ADEQUATELY SUPPORTED BREEDING PROGRAM CAN SOLVE THE PROBLEM

The development and growing of rust resistant varieties appears to be a promising method of rust control. Varieties or hybrid strains are now available which approach 100 per cent improvement in yield over the Haynes Bluestem commonly grown but 20 years ago. With Hope wheat available as a parent, the possibilities for further improvement are greater now than ever before. That additional work will pay large dividends on an increased public investment is beyond doubt. All of the experiment stations in the spring wheat area should be made 100 per cent efficient for this work. With adequate financial support improved varieties resistant to, or immune from, rust can be substituted for older varieties as rapidly and efficiently as is humanly possible.

The Role of Plant Breeding in Crop Improvement [a]

H. K. Hayes

It is the work of the plant breeder to produce varieties of crops which will bring a greater return to the farmers of the state or states which he serves. Much information is available that indicates the need for improvement in crop plants. Small grains will receive particular attention in this discussion. Among the desirable characters of wheat to be gained may be mentioned greater yield, better quality, stiffer straw, winter hardiness (for winter varieties) and most important of all, resistance to various diseases. In the spring wheat belt stem and leaf rust, smuts, root rots and scab are the most destructive diseases. With oats the general opinion is that higher yielding ability, stiffer straw, smut resistance and rust resistance are very important characters. In barley breeding, the following characters are of paramount importance: stiffer straw, greater yield, smooth awns and resistance to various diseases.

Considerable attention has been focused on breeding for disease resistance in recent years. In the making of new varieties by hybridization Pearl has stated "The plant breeder can and does use Mendelism as a direct and working guide. He has made Mendelism a working tool of his craft". It is evident, therefore that the present day plant breeder uses plant genetic principles as a very necessary part of his breeding program. The science of genetics is generally considered to be the foundation upon which plant or animal breeding is dependent. Other sciences are essential in a study of individual breeding problems. In many breeding problems it is essential to grow the experimental crop under normal conditions for the purpose of isolating the better sorts. Test conditions for many characters can be obtained by growing the material under controlled conditions. As an illustration breeders now are germinating corn under low temperatures to isolate the lines which grow normally under these conditions. In breeding for resistance to pathogenic diseases the organism which causes the disease must receive as much attention as the crop itself.

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[a] The suggestions and criticisms of Andrew Boss, F. R. Immer, F. J. Stevenson, and H. E. Brewbaker have been of material value.

Often an artificial epidemic of the disease must be created in order to give opportunity for rigid selection. Besides the genetic factors for resistance or susceptibility carried in the host plant there may be genetic factors in the pathogene which must be considered. Because of the nature of the problem there is much to gain by a cooperative attack on disease resistance with the geneticist and pathologist in the major roles. Such cooperative studies have been under way in Minnesota for slightly more than ten years.

A number of varieties highly resistant, or immune, to certain diseases have been produced in recent years. Several others will be released for distribution soon. This production of varieties of small grains which are resistant or immune to the more destructive diseases cannot help but be an important step in the direction of taking some of the hazard out of farming. When disease resistant varieties are available, the farmer will no longer be entirely at the mercy of some of the more destructive plant diseases. He can sow his crop in the spring with the assurance that disease at least will not take its large toll before the crop can be harvested.

Some of the new varieties of grains introduced by the Minnesota Experiment Station furnish a good illustration of the value of cearal crops breeding. Breeding winter wheat in Minnesota is conducted cooperatively by the Federal Department of Agriculture and the Minnesota Station. Minturki winter wheat was first released for distribution in 1917. This variety combines the winter hardiness of its Odessa parent with the desirable agronomic characters of its Turkey parent. In addition it is rather resistant to black stem rust. At the present time about 75% of the winter wheat grown in Minnesota is of the Minturki variety. It not only has replaced largely the other varieties of winter wheat but it is giving substantial returns where spring wheat could not be grown at a profit. Southern Minnesota now grows about 220,000 acres annually whereas only 89,000 acres were grown in 1922.

Velvet barley, a smooth awned variety, was first distributed to the farmers in the spring of 1926. It was obtained from crossing a smooth awned selection with a desirable rough awned 6-rowed variety. The smooth awned parent of Velvet was susceptible to "Spot blotch" caused by Helminthosporium sativum. Velvet is as resistant as varieties commonly grown in this region. The annual seed list of the Minnesota Crop Improvement Association lists for sale this spring 80,000 bushels of Velvet barley, 67,000 bushels of which is registered seed. This variety has found favor not only in practically every part of Minnesota but in neighboring states as well.

This spring large quantities of seed are being sent to neighboring states, some of the orders being for carload lots.

In some cases hybridization is not necessary as desirable strains may be selected from commercial varieties. Gopher oats is the most popular early oat grown in southern Minnesota. It is the result of a plant selection from a commercial early variety for the purpose of isolating a stiff strawed, high yielding strain. It has yielded considerable more than the varieties grown by farmers in demonstration trials made by Ralph Crim, Extension Agronomist.

The Minnesota Crop Improvement Association also lists for sale 12,000 bushels of Winona and Chippewa flax of which 7200 bushels are certified or registered. These new flax varieties have made possible the growing of flax on old soil which contains the wilt disease organism. The Minnesota varieties are a result of co-operative breeding studies by pathologists and plant breeders. Equally important wilt resistant varieties have been produced in North Dakota.

Studies with oats in Minnesota prove the value of breeding for disease resistance. From crosses of Minota and Victory, which are desirable yielding varieties, with White Russian, which is resistant to stem rust, over 300 lines, which are stem rust resistant, were selected and grown in rod row trials. Several of these have been tested also in 1/40 acre yield trials. One variety has been named Anthony and has been placed on the recommended list in Minnesota. Anthony yielded 16.8 per cent more than Victory for the crop years 1925 to 1927 inclusive in 1/40 acre trials made in six localities and yielded 62.5 per cent more than Victory in 1927.

Anthony and two other stem rust resistant selections were crossed with Black Mesdag which is immune from both covered and loose smut. Several double crosses were grown in rod row trials in 1927. Thirty-four lines were grown at Morris, Crookston, Waseca, and U. Farm in rod row trials, and several yielded as much as 17 per cent more than Victory. They were immune from smut and highly resistant to stem rust. Over 300 lines were tried in rod row trials at U. Farm. Several disease resistant selections yielded 100 per cent more than Victory.

New varieties of spring wheat which are resistant to both stem and leaf rust have been developed and small amounts of seed of some stem rust resistant sorts are available and are being increased by the Minnesota Experiment Stations for distribution in 1930. These studies are conducted cooperatively by the Minnesota Stations and the Office of Cereal Crops and Diseases, U. S. Department of Agriculture. Marquillo, which resulted from a cross of durum and common wheat, is the most promising new variety which has been tested widely in Minnesota.

It is not only resistant to stem rust, but is somewhat resistant to leaf rust and highly resistant to bunt and loose smut. It is rather susceptible to root rots although no worse, apparently, than some other common bread wheats. The color of loaf under some conditions is rather yellow. In the Red River Valley of Minnesota, it has given good yields and, when rust is severe, it has proven more satisfactory than Ceres, a North Dakota production. Only 130 bushels of seed of Marquillo are available for increase in 1929. Ceres has been placed on the recommended list in Minnesota as it is the best rust resistant variety available to farmers. The development of Marquillo proves that desirable wheats can be produced from species crosses. The more recent productions of McFadden, from crosses of Emmer and common wheats, are further proof that it is possible to obtain desirable recombinations of characters from species crosses. The new variety, Hope, and other selections from McFadden's crosses have opened new possibilities to the breeder.

A hybrid from a species cross may be used as a parent in producing even better varieties. Double crosses of Marquillo with selections of Kanred x Marquis have been studied and one year's rod row trials are available for several of these selections. Several yielded over 35 per cent more than Marquillo as an average of 4 trials made in 1927 in Minnesota, and they are more resistant to stem rust than Marquillo.

The mode of attack in plant breeding is no longer in the experimental stage. From a knowledge of the laws of inheritance and from previous study of the different varieties of grains, the trained plant breeder can now outline a given breeding project and methodically carry it through, step by step, with every assurance of success. The production of a desirable variety or the failure to obtain the desired end result is no longer entirely a matter of chance. The chances of success, however, are directly in proportion to the number of individuals used.

The first step in the solution of a breeding problem is to determine what end results are to be sought. Next it is necessary to obtain the best material possible with which to begin the breeding program. If disease resistance is one of the characters desired, the active cooperation of the plant pathologist is essential. The resistance of a variety to a certain disease in one region is no assurance of its resistance to possible different forms of this disease in widely separated areas or the same area.

If a variety seems to contain within it the characters desired in the new variety and is sufficiently variable, an improved strain may be obtained by selection within this variety. The production of a new variety by plant selection within an established variety takes about 8 or 9 years. That length of time would elapse before the new variety could be released to the farmer.

Many times, however, the desired characters are not all to be found in a single variety. In that case the plant breeder resorts to hybridization to gain his ends. Crosses are made between two variables both of which contain characters desired in the new sort. In the generations following the crossing of these two parental varieties, selection is made of those types which combine the desired characters of both parents. Many lines breed true by the fourth or fifth generation after the cross. If all the desired characters are not found in any two varieties, however, it may be necessary to continue crossing with still other varieties until the desired end results have been reached by a synthetic building up of the characters of the desired variety. After producing pure breeding sorts, they must be tested in comparative trials for several years.

The production of a new variety by hybridization would take about 12 or 13 years under the breeding and testing system now being used at the Minnesota Experiment Station. If necessary, this time could be shortened somewhat but, in general, this would not appear desirable.

I have endeavored to indicate to you that plant breeding is an application of plant genetic principles. Knowledge of crop characters and the manner of reaction of particular strains under different environmental conditions, and when possible the reason for the same, is as essential as a knowledge of genetics. In breeding for disease resistance, cooperation between plant geneticists and plant pathologists is certainly desirable. If resistance to disease is needed, for example resistance to black stem rust, it is necessary, as a rule, that a cross be made between a resistant wheat which lacks some desirable agronomic characters and a wheat susceptible to black stem rust which is as satisfactory as possible in its agronomic characters. Besides resistance and susceptibility, it is necessary to breed for other characters such as quality of seed and baking qualities of loaf, yielding ability, etc., which makes plain that even when disease resistance is the major factor to be gained that the problem remains primarily a plant genetic one.

Many disease organisms consist of strains which can be differenciated only by their mode of reaction on certain varieties. Two general methods for determining the reaction to disease are used in breeding for disease resistance to pathogenic organisms.

1. A collection of all strains of the disease organisms may be made and cultures of the same propagated. These cultures are used to produce the artificial disease epidemic in the field. Selection is possible, under these conditions, for resistance to the various strains of the disease.

2. Short rows of selections of new crop varieties or strains are grown in many different localities and disease reaction studied under normal field conditions. By a combination of these two methods, considerable assurance can be gained of the expected disease reaction of the new variety.

In breeding for resistance to a certain disease, it is necessary to consider reaction to all other important diseases. A disease nursery or nurseries is as essential as a nursery or nurseries for the study of agronomic characters.

The question which needs definite consideration this morning is how can we improve our pesent wheat breeding program? Some believe that the extensive trials of material now available is the most important phase. It is true that all possible trials which could have been made with present facilities have not been made but, for the more promising wheat selections, the available tests are sufficient to prove that certain characters need further improvement. The breeder can predict, with a considerable degree of accuracy, what the possibilities of any particular cross are. If chance plays the major part in his selections, and it surely does if all important characters are not studied during the segregating generations, then luck is the major factor in deciding the success attainable from a certain cross. Luck would be a minor factor if reee search facilities were available for studying in the segregating generations all important agronomic characters such as grain plumpness, texture, protein content, period of maturity, botanical character differene ces and stiffness of straw and if, in addition, facilities were available for a study of reaction to all important parasitic diseases. As a result of studies in Minnesota, it appears that grain plumpness is a very important character and directly related to yield.

This appears to be true even after holding constant the effect of reaction to such diseases as black stem rust. Intensive selection for plumpness is desirable during the segragating generations and a study of genetic factors which determine relative plumpness appears fundamental. Other agronomic characters need intensive study also.

The breeder needs also the aid of the cytologitt when species crosses must be undertaken. Histological studies in relation to strength of straw ans other characters would be of material aid. Much more study of the factors which are related to milling and baking quality are desirable.

A study of hundreds of selections and their progeny for all important characters takes more men, time and money than are now available. The success or failure of a breeding program would no longer be a matter of luck if the breeder could make extensive studies of his material. The speaker believes that, in the past, the chief lack has been that it was impossible to apply plant genetic principles directly to all the essential phases of a breeding program for a scientific application calls for more detailed study than was possible with the men and money that have been available. At least four to six added assistants and several thousand dollars for labor are needed in Minnesota to effectively place our breeding program on a sound basis. There is no doubt but that additional funds could also be profitably employed in other localities where breeding is under way or is to be undertaken.

THE INTERDEPENDENCE OF THE GENETICIST AND PATHOLOGIST IN WHEAT BREEDING, AND THEIR WAY OF WORKING TOGETHER.

E. C. Stakman

Progress in the development of disease-resistant varieties of wheat depends largely on the interaction--the degree of cooperation--between the geneticist and the pathologist. The diseases themselves are the result of the interaction between the host plant and the pathogene. In considering our destructive wheat diseases we must remember that we are dealing with two living things: the wheat plant and the fungus or bacterium that parasitizes it. The job of the geneticist is to know and improve wheats; the job of the pathologist is to know the parasites and prevent their development.

The ideal method of controlling wheat diseases is the use of disease-resistant varieties. It is the best method--when it can be used successfully. It is true that some diseases, the smuts for instance, can be prevented by seed treatment. But seed treatment requires labor and money and, even though it is inexpensive, many farmers do not treat their seed. Therefore it is highly desirable to develop smut-resistant varieties even though simple methods of control are now available. And the most destructive diseases--the rusts, wheat scab, and the root--and foot-rots--can not be controlled adequately by any method available to the individual farmer. These diseases cause enormous losses. From 1915 to 1920 inclusive black stem rust destroyed on the average almost 45,000,000 bushels of wheat annually in the Dakotas and Minnesota. From 1921 to 1926 inclusive the average annual loss was more than 11,000,000 bushels. Wheat scab often reduces wheat yields as much as ten per cent, especially in those areas where corn is grown extensively. It is difficult to estimate accurately the damage caused by root-rots, but I have often seen fields in which from ten per cent to forty per cent of the heads were killed. The orange leaf rust has not done a great deal of damage in the past, because many of our hard red spring wheats and the durums are somewhat resistant. But some of the newer varieties, such as Kota, Ceres, Ruby and Quality are very susceptible and were injured considerably in 1927. The eradication of the common barberry is reducing losses from stem rust. But most plant pathologists probably admit that it will not eliminate them entirely. And the other diseases mentioned can not be prevented entirely by any method now available. Therefore, it is absolutely essential that we produce disease-resistant varieties if we are to continue to grow wheat successfully. It is desirable to combine in one variety resistance to all of these diseases. That, however, is not easy to accomplish. But it is the thing which we must attempt.

One of the most difficult problems confronting us is the fact that there are so many parasitic strains or physiologic forms of the fungi causing these diseases. There are about fifty parasitic strains of the variety of black stem rust which attack wheat. Some varieties are resistant to some of these strains and completely susceptible to others. No known variety is resistant to all of them. There are at least a dozen parasitic strains of the orange leaf rust of wheat; there are probably at least one hundred parasitic strains of the fungus which causes most of the root-and stem-rot of wheat; and recently it has been discovered that there are parasitic strains of the wheat scab fungus. It is necessary, therefore, to produce varieties which are resistant to all or most of the parasitic strains which occur in the region for which the varieties are intended. In order that breeding work may rest on a firm foundation, it is necessary to know how many of these parasitic strains there are; it is necessary to know their geographic distribution; it is necessary to know whether they migrate from one region to another; and it is necessary to know their effect on varieties already in existence and those which are being produced. The time to ascertain their effect on new varieties is before the varieties are distributed, not afterwards.

Not only are there many parasitic strains of these disease-producing fungi now, but new ones also may be introduced from other regions, and new ones probably are being produced constantly by hybridization or mutation or both. How rapidly are new forms being produced? How virulent are the new forms and what is their significance in the breeding of resistant varieties? These things the pathologist must find out and the plant breeder must know.

Not only are there many parasitic strains of our most destructive disease-producing fungi, but new ones may be introduced from other regions. We try to prevent this by plant quarantines, but, at best, quarantines are not completely effective, and we can not prevent the wind from carrying spores hundreds of miles. It is probable therefore that we shall make the most rapid progress in the end by subjecting our varieties, while in the making, to all of the parasitic strains present in a natural geographic region. But we should prevent the introduction of new strains from regions separated from ours by natural barriers. Even if we do not complicate our problem by introducing new parasitic strains, nature probably will continually complicate it for us by producing new strains by hybridization and mutation. We know from the work of Craigie that there is a strong liklihood that parasitic strains of stem rust hybridize on the barberry, and we know that strains of smut fungi hybridize. Furthermore, we know from the work of Miss Newton and Johnson that color mutations occur in wheat stem rust; and Levine and I have strong ciruumstantial evidence that mutations in parasitism occur also. Christensen has shown that some strains of <u>Helminthosporium sativum</u>, the principal cause of root-rot, mutate and that some of the mutants are more virulent than their

parents. Some of the smut fungi, particularly the corn smut fungus, mutate so fast that one can scarcely keep track of the new strains. These facts simply show that while we are producing new varieties of wheat nature is producing new parasitic strains of the fungi that attack it. But is there any evidence that these facts are important in our problem? There is.

For a number of years some of the milos, feterita, and hegari were very resistant to or immune from kernel smut of sorghum. But a few years ago some of them appeared to lose their resistance. The resistance was not lost at all. New and more virulent parasitic strains of the smut fungus made their appearance. It has been shown by Tisdale, Melchers, and Clemer that there are at least three parasitic strains, and none of the previously resistant varieties is resistant to all of them. There is evidence that one of the strains may have arisen by hybridization. The experience with Kanred wheat is well known. A number of years ago Kanred was distributed as a stem-rust immune, hard red winter wheat. It is immune from about a dozen parasitic strains of the wheat stem rust fungus but is completely susceptible to others. Therefore, it rusts heavily in some years and in some regions, for example, it was so heavily rusted in western Nebraska in 1923 that farmers became discouraged and have refused to grow it there since that time. A few years ago an intensive program of developing bunt-resistant wheats was begun in the Palouse district of the Pacific Northwest. Several varieties which appeared immune were developed. In the meantime, however, it was discovered that there are parasitic strains of both of the fungi which cause bunt. New strains of the smut fungi appeared in the Palouse district and, within the past year or two, some of the previously resistant wheats have begun to smut heavily. Now it is necessary to start over again, and take into consideration the parasitic strains which are present in that district.

There have been other similar experiences in the past and there will be similar ones in the future. In our breeding work, therefore, we must take an intensive study not only of the host plant but also of the pathogenes which cause the disease of the host. Therefore, I cannot agree with all of the statements made by the speaker previous to the last regarding Hope wheat. It is true that Hope appears to be generally resistant to black stem rust and several other destructive diseases. But when we consider the experience with smut-resistant sorgums, with Kanred wheat, with bunt-resistant wheats in the Northwest, we begin to realize the value of caution. Possibly Hope wheat may be resistant to the parasitic strains of rusts and smuts now in existence and those to come. It is devoutly to be hoped that it will, but I should not want to promise it.

Perhaps this recital of difficulties seems pessimistic. To me it seems like realism rather than pessimism. We are making war on wheat diseases, and it is a sound principle of warfare to learn as

much as possible about the strength and resourcefulness of the enemy. In this case the enemy are the pathogenes which cause disease. The part of wisdom is not to blind ourselves to the strength and versatility of the pathogenes, but to learn as much as we can about them and try to keep several moves ahead. This can best be done by the combined efforts of pathologists, geneticists and plant breeders.

Possibly all of these parasitic strains are not as formidable as they appear to be. Aamodt has shown that the same genetic factor may govern the immunity of Kanred wheat to several strains of the wheat stem rust. There is some hope in that. Hursh showed that some varieties of wheat may be resistant to most parasitic strains because of structural characters. And Miss Hart recently has obtained evidence that certain wheats may prevent the entrance of rust by keeping their breathing pores closed most of the time. Possibly we can breed wheats which, because of these structural and functional pecularities, can withstand the attacks of most parasitic strains. That remains to be seen.

The geneticist and pathologist are interdependent. The most rapid and permanent progress depends on their combined efforts. The pathologist must contribute facts regarding the parasitic peculiarities of the pathogene, the factors affecting the development of diseases, and the nature of resistance. The geneticist must study the mode of inheritance of disease resistance in combination with other desirable characters in the host plant. The knowledge and technique of geneticist and pathologist must then be combined by the plant breeder, whatever his official designation.

How can the geneticist and pathologist work together? Simply by actually working together. We must submerge our special viewpoints and interests in the common desire to contribute to the production of better disease-resistant varieties.

It is seldom that one man has the necessary training, to say nothing of the time, to study intensively both the host plant and pathogene, but a study of both is necessary. Therefore, we must work together. The next speaker comes about as near to combining the knowledge regarding the pathogene and host plant as any one I know. As a matter of fact, he is a living demonstration that a geneticist and pathologist can work together in one individual--a hybrid, as it were, who combines some of the qualities of both.

Much progress has been made in the development of disease-resistant varieties in the past and much more will be made in the future. I believe as sincerely as any one here that some of our most destructive diseases of wheat can be controlled adequately only by the use of resistant varieties. And my faith in the development of such varieties is not destroyed by the difficulties I have pointed out. Surely there can be no virtue in minimizing or ignoring the magnitude of our task, and on this point I want to be very emphatic: if we are to make progress most rapidly and surely, it is absolutely essential that we make more fundamental investigations. Geneticists and pathologists must combine to study thoroughly the host plant and the pathogene. Then and only then will we make progress as rapidly as we should.

THE INTERDEPENDENCE OF THE GENETICIST AND PATHOLOGIST IN WHEAT BREEDING AND THEIR WAY OF WORKING TOGETHER

Olaf S. Aamodt

The foundation for what I wish to say regarding the production of a disease-resistant wheat has been well laid by the previous speaker, Dr. Stakman. The importance of physiologic forms of the various disease-producing organisms can scarcely be overemphasized. They have accounted, to a large extent, for the great amount of variation in reaction to disease which certain supposedly resistant varieties have exhibited at various times in the past. A complete understanding of this variation was not forthcoming until the discovery of the existence of numerous physiologic forms by Dr. Stakman and his co-workers in 1917 and the years following.

From the plant pathologist's point of view there is a certain amount of fundamental information regarding the life cycle of an organism which is necessary to an intelligent understanding of the problem. The plant breeder who wishes to test numerous varieties and hybrids for their disease reactions must have certain of these fundamentals well in mind. He must understand and be able to manipulate those factors in the life cycle of an organism which condition infection. He should have information regarding the number, prevalence and distribution of the physiologic forms of the pathogene with which he is dealing. As a basis for the breeding operations he should know the varietal reaction of the host to particular forms and then deal with such reactions between the host and parasite as definite genetic characters. The desirability of combining the resistant reactions of the host to the various pathogenes with good agronomic characters brings us into the field of the geneticist.

The inheritance of disease resistance may be complicated, not only because of the presence of many and varied forms of the pathogene, but also because disease resistance is the result of the interaction of two elements, i.e., the host plant and the parasite. Information regarding the mode of inheritance of reaction to the various organisms aids materially in deciding how extensively any particular cross must be studied. The genetic relationship between such characters as quality of seed, earliness of maturity, strength of straw, and seed shattering, on the one hand, and disease reaction, on the other, is of fundamental importance to the plant breeder.

How are we going to get the various facts and fundamental principles which have been worked out by the geneticist and plant pathologist focused upon a joint program of crop improvement? In the past, numerous varieties have been produced, and often distributed to the grower long before any exact information re-

garding their disease-resistant capabilities was made known. Likewise in the breeding plots many selections are increased with the hope that when they are ready for distribution they will be found to have inherent resistance to the more important diseases which are present in the region where they are to be grown. Such a system is not only unscientific but also poor economy. The primary factor which inhibited the carrying on of a more comprehensive and thorough improvement program in the past has been the lack of funds.

The point at which we can most effectively and economically apply the principles of both the geneticist and plant pathologist to a comprehensive wheat improvement program is in the earlier segregating generations. It is here that we can study and accumulate knowledge regarding the mode of inheritance of the more important characters and at the same time eliminate the bulk of the material which is of no promise. This particular mode of attack has been developed in the form of a disease garden. It may be favorably compared to the proving grounds of a modern automobile manufacturer who puts his new car, or new appliance, through a severe test on a scientific experimental basis before it is released to the consumer. The car does not need to be bought on the basis of the superficial appearance, or performance under some especially favorable local conditions, but rather on its merits as shown by the producer on the experimental grounds.

On the plant breeder, whether he happens to be professionally a geneticist, plant pathologist, physiologist, or agronomist, falls the responsibility of applying the fundamental principles put forth by these various groups to the varietal or hybrid material in the breeding plots. For a number of years artificial epidemics of stem rust have been used in the field to insure, as far as possible, the opportunity for all varieties to come in contact with all of the physiologic forms. An artificial epidemic of stem rust is produced in the breeding plots by spraying the plants with a spore suspension of urediniospores and by transplanting cultures of rusted wheat to the field. This is supplemented with material collected in areas in which natural epidemics occur. The rust spores from such collections are used either to dust or spray the plants in the rust nursery. A second method consists of growing the promising new productions at various stations in the regions in which they are expected to be grown later. In the first method the parasite is brought to the host plants in the breeding plots, while in the second method the selections are taken out and exposed to the natural epidemics of rust in the field.

There are certain other diseases present in the spring wheat region which may possibly become important limiting factors in production. In the breeding work we are producing new combinations of characters. Some of these characters may be susceptible to diseases which are already prevalent, but not destructive because the present varieties are resistant. The disease garden

is the place to catch the possibilities of such occurrences for new diseases as well as those which are already well known. The disease garden is grown as a duplicate of the rust nursery, as some diseases inhibit or accelerate the development of others. A rust-resistant variety of wheat, resistant also to such destructive diseases as bunt, loose smut, orange leaf rust, foot rots, scab, etc., is much more likely to produce a successful crop than one which is susceptible. Consequently, in the disease garden artificial epidemics are produced of all of these diseases. Special attention is paid to the use of as many physiologic forms, of each disease, as possible. A variety of wheat, or a new hybrid selection, which can survive the perils of such a test has a much greater possibility of being a disease-resistant variety than one which has been produced under conditions where these factors are ignored.

The multiplicity of problems which must be solved in producing a new variety of wheat necessitates the cooperation in many related fields of study. We must always be looking forward to changing conditions. New diseases, different environmental conditions due to drainage, rotations, etc., new market demands, new methods of harvesting such as the combine, are all indications of the demands for crop improvement not only for this day but also for the future. Crop improvement is a permanent program, and provision for carrying on the work should be made accordingly.

PLANT BREEDING FOR RUST RESISTANCE AT THE DOMINION RUST RESEARCH LABORATORY, WINNIPEG, MANITOBA.

C. H. GOULDEN, SENIOR CEREALIST

As the plant breeding work at this laboratory progresses and as new facts regarding the inheritance of rust resistance are brought to light we feel more and more optimistic with respect to an ultimate solution of the problem. This last season in particular, was a very fruitful one. It furnished an abundance of new and valuable material and the fundamental studies yielded results far reaching importance. In this report we propose to discuss the work under two heads.
(1) The general plan of attack and progress in the production of rust resistant strains of common wheats. (2) Fundamental studies on resistance in varieties and its inheritance.

Plan of Attack and Progress

The hybrid nursery in 1927 consisted of five and a half acres of head-row plots. The material contained in this nursery is shown in Table 1. The table also shows the generations that will be grown in 1928.

Table 1. Summary of hybrid material and generations to be grown in 1928.

Crosses	Generations Grown 1928				
1. H-44-24 x Marquis	Rod Rows	F_4	F_3	F_2	--
2. Marquillo x Garnet	Rod Rows	F_4	F_3	--	--
3. Double Cross x Ceres	Rod Rows	F_4	F_3	--	--
4. Marquillo x Reward	Rod Rows	F_4	F_3	F_2	--
5. Pentad x Marquis	--- ----	F_4	F_3	--	--
6. Double Cross x Marquis	--- ----	--	F_3	--	--
7. Double Cross x Kota	--- ----	--	F_3	--	--
8. Double Cross x Garnet	--- ----	---	F_3	--	--
9. Reward x Ceres	--- ----	--	F_3	--	--
10. (Pentad-Marquis) x Marquis	--- ----	--	F_3	F_2	F_1
11. H-44-24 x Reward	--- ----	--	F_3	F_2	--
12. H-44-24 x Marquillo	--- ----	--	F_3	F_2	--
13. (Marquis-Kanred) B_{2-5} x Marquis	--- ----	--	F_3	F_2	--
14. (Pentad-Marquis) x Garnet	--- ----	--	--	F_2	--
16. (Marquis-Kanred) B_{2-5} x H-44-24	--- ----	--	--	--	F_1
17. Double Cross x H-44-24	--- ----	--	--	--	F_1
18. (Marquis x Acme) x Marquis	--- ----	--	--	--	F_1
19. Webster x Marquis	--- ----	--	--	--	F_1
20. Webster x H-44-24	--- ----	--	--	--	F_1
21. Double Cross	--- ----	--	--	--	F_1
22. Hope x Reward	--- ----	--	--	--	F_1
23. Hope x Marquis	--- ----	--	--	--	F_1
24. Black Persian x Marquis	--- ----	--	--	--	F_1

It is not possible here to indicate clearly the extent to which each cross is being studied nor which are considered to be of the most importance. For each cross there is a fairly definite objective but it will suffice to point out that the crosses fall into three groups.

Group 1. Rust resistant parents are crossed with good yielding high quality wheats. As examples we have H-44-24 x Marquis, Marquillo x Reward, and so forth. From such crosses we expect in the first attempt to obtain strains of good yield and quality with a satisfactory amount of resistance for the time being.

Group 2. In this group the parents on both sides possess some resistance the object being to combine the resistance of both and to use the strains derived in this way in other crosses similar to those under group 1.

Group 3. These are interspecies crosses. They represent a very fundamental first step in breeding work. Resistance is on the whole found in the 28 chromosome group and when through interspecies crosses this resistance has been transferred to the 42 chromosome group the newly derived strains can be utilized in further crosses in wheats of good quality or they c n be used as in group 2 for building up more complete resistance.

Turning now to the practical results that have been obtained Table 1 shows again that strains from certain crosses are being tested in rod rows in 1928. From the one cross H-44-24 x Marquis about 100 strains are being tested and these look very promising. In the field they are practically immune from rust, and are very good appearing strains that promise to yield well. Milling tests on the most desirable of these will be conducted by the Cereal Division laboratories at Ottawa.

Inheritance of rust resistance in one cross which was studied intensively and gave results of striking importance will first be considered.

The resistant parent in the cross is known as H-44-24 and was produced by Mr. E. S. McFadden of Webster, South Dakota. It came from a cross of Marquis x Yaroslav emmer. During the past three years it has never shown more than a trace of rust in field tests conducted by the pathology staff of this laboratory. Similar results are being reported from the four American states in which rust is prevalent. Agronomically this variety is probably not of much value as it is very short in the straw, is heavily bearded and the glumes are so persistent that threshing is very difficult. As to the quality of the grain very little is yet known but one test made by the Cereal Division laboratory at Ottawa gave quite satisfactory results.

The susceptible parent in the cross was Marquis.

The hybrid progenies from the cross were tested to two physiologic forms, 21 and 36. Marquis is quite susceptible to both forms. H-44-24 is highly resistant to form 36 and moderately resistant to form 21.

The first generation plants were grown in the greenhouse during the winter of 1925-6 and seedling plants were tested to the two forms. An interesting feature of the resistance of F_1 plants was observed when these were tested to form 21 at different stages of maturity. Although quite susceptible in the seedling stage they were quite highly resistant when about six weeks old and at heading they were practically immune. This result indicates the possibility of the presence of factors for a mature plant type of resistance which completely covers the susceptibility evident in the seedling stage.

In the remaining studies of the hybrid populations efforts were concentrated on determining the factorial condition for seedling resistance to the two physiologic forms and the agreement between field and greenhouse tests.

In the seedling stage resistance to form 36 was found to be dominant and governed by two pairs of factors. Resistance to form 21 was recessive and probably also governed by two pairs of factors.

In the field the results were quite different. The 1000 families that had been tested in the greenhouse were grown in the field and detailed observations made on the segregation for resistance. These families were found to give a fairly close 1:2:1 ratio of resistant, segregating and susceptible lines. This indicated that only a single pair of factors was operating for field resistance and when the results were compared with those obtained in the greenhouse there was a complete lack of agrrement. Table 2 shows the behavior in the field of the two groups of strains, one group uniformly susceptible in the seedling stage and the other group uniformly resistant.

Table 2. Behavior in the field of two groups of F_3 lines

		Field Reaction			
		Res	Seg	Susc.	Totals
Seedling reaction to forms 36 & 21:	Homozygous Res.	8	18	10	36
	Homozygous Susc.	6	18	8	32
		14	36	18	68

This is in the form of a contingency table and any relation between the results can be determined by calculating the value of X^2. In this case $X^2 \pm .275$ and for 2 degrees of freedom $P = .85$. This value shows that any relation between the results would occur by chance in 85 out of 100 trials, and therefore is a very decided indication that field resistance is in this case inherited independently of greenhouse resistance as determined in the seedling stage.

These studies have been followed up by tests on the F_4 generation in the greenhouse. Twenty-two lines that were breeding true to rust reaction in the seedling stage to forms 21 and 36 were tested to five other forms. The results are as given in Table 3.

Table 3. Seedling reactions of twenty-two selected F_3 lines of H-44-24 x Marquis to seven physiologic forms.

Field Re-action	Strain No.	Physiologic Forms						
		9	14	15	17	21	34	36
Susc.	7	2 3-	2 3	3±	2+ 3-	2 3	2 3	
"	204	2	2 3	3±	2.	2 3-	2 3	1
"	293	2 3-	2 3	3+	2+ 3-	2 3	3 3	1
"	456	2+ 3-	2- :1	3±	3-	2 3	2 3	1
"	572	3	2 3	3	2+	2 3	2 3	1
"	587	3	2 3	3+	2+	2 3	2 3	1
"	885	2+ 3-	2 3-	2+ 3.	2.	2 3	2 3	1
"	937	3+	2 3	3+	3-	3-	3-	1
Res.	128	2 3+	2 3	3+	2 3	2 3	2 3	1-
"	386	2 3+	2 3	3+	3	2 3	3±	1-
"	725	2 3.		3+	2 3	2 3	2 3.	1-
"	880	2 3	2 3	3+	2 3	2 3	2 3	1-
"	888		2 3	3±.	3	2 3	3	1-
"	903	2 3	2 3+	3±	2 3	2 3	2 3	1-
Res.	99	4	1-	4	3±		3+	
"	148	3+	1	3+	3+		3+	
"	179	3+	1	4.	3+		3+	
"	208	4.	1	4	4.		4.	
"	221		1	4+	3+		3+	
"	331	3+	1	3±	3+		3+	
"	450	3 4-	1+	3±	3.		3+	
"	875	4	1.	4	4-		3+	

These results indicate that factors governing high resistance to one or more forms may also govern the reaction to one or more other forms and the reaction to the latter may be only moderate resistance or perhaps susceptibility. In this case we find that two factors responsible for the moderate resistance of H-44-24 to six forms, are allelomorphic to factors responsible in Marquis for high resistance to form 14 and complete susceptibility to the other five. The factor relations and rust reactions in both parents may be responsible as follows:

	H-44-24		Marquis
	M R-9		S-9
	M R-14		R-14
RR	M -15	rr	S-15
	M R-17		S-17
	M R-21		S-21
	M R-34		S-34

R = resistance
S = susceptibility
M R = moderate resistance
M S = " susceptibility

Another project under way which may be classed as a fundamental study is the testing of wheat varieties for resistance in the mature plant stage. This work is under way in the greenhouse at present. Fifteen varieties, chiefly the resistant parents in our crosses, are being tested separately to fifteen different physiologic forms. This work is very important from the standpoint of our breeding work because we know now that seedling tests do not tell the whole story regarding the resistance of a variety and we must have complete knowledge before the breeding work can be intelligently directed.

Recent discoveries by other investigators and to some extent the results reported here have brought about some changes in the view-point of plant breeders with regard to the entire problem of breeding for rust resistance.

Newton and Johnson have shown that color mutations occur in rust forms. Mutation of course is an expected rather than an unexpected phenomenon in all organisms but this is the first real proof of its occurrence in rust fungi. Mutation in rust forms with a resulting change in parasitism have not been proven but there is circumstancial evidence that such changes do take place, and the occurrence of color mutants indicates that this is a real possibility. Craigie has shown that rust forms may hybridize on the barberry and this opens up further possibilities with respect to the production of new rust forms.

We see therefore that nature has perhaps provided for the wholesale production of new physiologic forms and if these differ very distinctly from the old forms in parasitic capabilities it is evident that breeding for resistance to all of these forms may be too immense a task to be undertaken with a reasonable expectation of success. This should not deter the plant breeder, however, until it can be shown the gybrid or mutant forms definitely possess new parasitic characteristics.

Our own studies, however, on the nature and inheritance of resistance tend to offset the alarming possibilities with regard to the multiplication of physiologic forms. These forms are differentiated entirely on the basis of seedling reactions and some varieties such as Acme, Pentad, Hope, H-44-24, and Kota that are susceptible to a number of forms in the seedling stage appear to be resistant to all forms in the field. Kota shows the least resistance of any of these varieties in the field but its resistance is appreciably greater than in the greenhouse in the seedling stage. Acme and Pentad are both highly resistant in the field. Hope and H-44-24 are vulgare derivatives from a Marquis x emmer cross by McFadden. In the field they appear to be the most resistant varieties that have as yet been observed, while in the seedling stage they are only moderately resistant or moderately susceptible to several forms.

The discrepancy between field and greenhouse results cannot be completely explained until more is known regarding the nature of resistance, especially of the type of resistance exhibited by plants approaching maturity. Hursh has presented evidence to the effect that the resistance of such varieties as Kota is morphological. Such a type of resistance depending on the proportion of sclerenchyma to collenchyma in the plant would not be expected to show until the plant was fairly well developed. But more evidence is necessary in order to show that such is the case in all of the varieties mentioned. The important fact is that physiologic forms are differentiated by tests conducted in the seedling stage and if another type of resistance shows up at a later stage it may have an entirely different relation to the physiologic forms. If it is physiologic it may split the forms in a different manner or it may perhaps throw them all in one group. If the resistance is morphologic or of such a nature as to throw all the forms in one group, rust may be regarded as an entity in relation to plant breeding technique when dealing with varieties such as Acme, Pentad, or H-44-24, and the occurrence of a greater number of forms varying in parasitic capabilities only in so far as the seedling stage of wheat varieties is concerned, will not be an appreciable factor.

These facts, however, do not deprecate the importance of further research with physiologic forms. They tend rather to emphasize the importance of research along slightly different lines. We must know for example what reactions our parent varieties give to different forms when tested in the mature plant stage as well as in the seedling stage and at all costs we must know the complete possibilities with regard to the production of new forms by mutation and hybridization. The existence of a type of resistance in some varieties that applies to all forms does not by any means eliminate the possibility of the production of new forms to which these varieties are susceptible. Further research to determine what nature has in store for us along this line seems to be absolutely essential to the plant breeding viewpoint.

THE RELATION OF THE CEREAL CHEMIST TO A WHEAT BREEDING PROJECT

C. E. Mangels

Earlier work in plant breeding was concerned principally with readily recognizable plant characteristics, such as color of flowers. Plant breeding has now been extended to include plants of economic importance such as the cereals. In case of cereal crops, the plant breeder is often dealing with characters which are not readily recognizable. The plant pathologist has assisted, in the selection of disease resistant strains. The cereal chemist's function in wheat breeding projects is to assist the plant breeder in selecting types which are desirable from the quality standpoint.

The chemist's work is relatively more important in a wheat breeding project, than in projects with other cereals. Two objectives in cereal breeding are the development of varieties more resistant to disease and having higher yielding capacity. In the case of wheat, however, the new variety must also be satisfactory for the manufacture and production of certain food products-namely, bread, pastry or macaroni. The chemist now recognizes that probably no one wheat will be eminently suitable for more than one of the products mentioned. A wheat must be suitable, however, for the production of one class of products, and in the spring wheat belt we are primarily concerned with the production of high grade bread and macaroni wheats.

The quality of the manufactured products prepared from wheats is almost entirely dependent on the quality of raw material. Milling is essentially a mechanical process, and flour may be improved in quality only to a very limited extent, by chemical treatment (bleaching) or addition of other ingredients. One of, if not the principal function of a mill's laboratory organization today, is the selection of the raw material. The plant breeder, agronomist and chemist all appreciate the great importance of proper quality. They fully realize that a new wheat must not only have some advantage in regard to disease resistance and yield, but as compared to existing types must also be of equivalent or superior quality. It is generally recognized that the extensive introduction of new wheat types which fail to measure up in quality, may be a serious matter to both the milling industry and the wheat producer.

It is the chemist's duty to examine wheats and then assist the plant breeder to make selections from the standpoint of quality. How efficiently can the cereal chemist serve in this respect at present? At present, the service of the cereal chemist in selecting wheats for quality, is limited.

But while methods of testing wheat and flour developed by the cereal chemist have proved to be of great service to the milling industry in controlling quality of products, commonly used methods of testing wheat do not give sufficient basic information regarding new varieties. Special procedures should be developed for examining and evaluating new wheat types.

Cereal chemistry is a relativly new field of endeavor. The last decade has witnessed great progress in the field of cereal chemistry, but in spite of this progress, we still have only a very superficial knowledge of the chemistry of wheat and flour. The chemist can be of greater service in selecting quality wheats. when fundamental research in this field discolses more facts regarding factors which influence wheat quality.

The chemist recognizes the fact that glutens from different types of wheat differ in quality. A number of chemists have made important contributions to this question, but as yet the problem is not solved. We have, furthermore, for quite a long while assumed that the starch of wheat is "just starch". Recent investigations indicate important differences in the properties of wheat starches.

There are other ingredients in wheat and wheat flour besides protein and starch. These substances, it is true, may be present in very small quantity. I wish, however, to call attention to the fact that vitamine substances in foods are present in very minute quantities. Two decades ago vitamines were unknown, but today they have assumed an important role in nutrition chemistry. At present we know very little about the fatty substances in wheat-including the lipoid materials. There are also gums, resins, and ferments, which may have a profound effect on the quality of flour.

Every chemist engaged in cereal work realizes fully the great need for further fundamental researches on the constituents of wheat and flour, and their relation to quality. Where and how can these investigations be conducted? The commercial cereal laboratory usually does not have time and equipment available for such studies. The function of mill laboratories is control and maintainence of quality of products. Milling companies do not maintain laboratories strictly for fundamental research. Since quality of milling products are quite dependent on raw materials used, researches on wheat and flour chemistry are a production as well as a manufacturing problem. Wheat production is an agricultural problem and it is therefore quite fitting that the U. S. Department of Agriculture and the state experiment stations should support a research program of chemical investigations on wheat and wheat products. At the present time only five of the state stations are conducting work on wheat and flour chemistry. Considering the value of the wheat crop, the financial support for the work in these five stations is very inadequate. With more adequate financial support, the laboratories now engaged in this work could make some real contributions to this problem.

The cereal chemist needs therefore primarily more adequate support for fundamental research. While accumulating facts by such investigations, the cereal chemist can probably be of greater assistance to the plant breeder by some modifications and amplification of methods of testing flour now in use.

The controlled baking test still remains the principal method of testing flour. Recently the American Association of Cereal Chemists has given the baking test very critical study. The purpose of these studies have been not only the standardization of methods of procedure, but an effort has been made to modify the procedure so that the test would give a more positive answer regarding wheat and flour quality.

For assisting the plant breeder in making selections, variations of the standard baking procedure may be advisable. Swanson of Kansas has, for example, advocated the use of severe mixing. Instead of one standard baking test, a number of variable tests can be made on the same variety. Such tests will give better information regarding properties of the variety. This means additional work in the baking laboratory. A relatively small amount of additional work, however, would enable the chemist to be of much greater assistance to the plant breeder.

The possibilities for wheat improvement by plant breeding are not confined to disease resistance and yield. So far attention of the plant breeder has been focused on the development of wheat of superior disease resistance and yielding power. It is possible, however, to improve the quality of wheat as well as the yielding power. Marquis wheat, the outstanding commercial hard red spring wheat is the result of a cross, and is certainly superior in quality to its fife parent. Mindum durum, now recognized as having quality superior to Kubanka, is a result of a selection made at the Minnesota station. With only a partial knowledge of wheat and flour quality, we may discard wheats of superior quality. A more adequate support of a research program in cereal chemistry, will make possible more accurate and earlier selection of wheat for quality.

A FIRST APPROACH IN SECURING COMMERCIAL RUST-RESISTANT WHEATS.

L. R. Waldron

The United States is a great wheat producing country, the total annual production amounting to about 800 million bushels. It is interesting to note that the acreage sown to varieties known to be of hybrid ancestry produced as a result of definite breeding programs is comparatively small. Perhaps less than 25 per cent of the wheat acreage of the United States is devoted to such hybrid wheats, Marquis far exceeding any other variety.

A discussion of this fact, in comparison with what is found in certain other countries, would lead us along interesting paths. This country has always been on an export wheat basis, producing more than has been needed for home consumption. The fact that we have continually produced more wheat than we have been able to consume must be taken into account in connection with our small hybrid wheat acreage.

Let us consider Sweden for a moment. Years ago that country, which had always been upon an import basis, found its wheat acreage declining as imported wheat could be sold for less in Sweden than it cost to produce domestic wheat. The government interested itself in wheat breeding and at present, after 30 years of scientific work, the yield of winter wheat per acre in Sweden has increased above 40 per cent and as a result of this increase in yield per acre the acreage sown to wheat has shown material increases. At the present time the old native or Landsorten wheats are very largely discontinued, replaced by the new hybrid sorts.

But a country does not need to be upon an import basis to have wheat breeding given particular attention as New South Wales and Canada attest so fully. Particularly in New South Wales has wheat breeding been pursued with a striking singleness of purpose since its inception by Wm. Farrer in 1886. New South Wales devotes about 75 per cent of its wheat acreage to hybrid wheats and of the total production perhaps 65 per cent is available for export.

Reasons for Small Hybrid Acreages.

Why the Unites States has not taken a more important place in the production of hybrid wheats is due to a variety of causes. This country has a number of wheat areas none of which is of enough importance to dominate the total export quantity. The attention of the public has not been focused upon export wheat

as an important national income factor as is the case in Canada and New South Wales. In many parts of our country when wheat has ceased to be a profitable crop, because of diseases or lack of diversification, crop diveristy has been introduced which has resulted in placing wheat in a relatively minor position. Also relatively outstanding pioneer individuals, like Farrer of New South Wales or Nilsson of Sweden, have not made their appearance as wheat breeders in this country. The existence of this Conference forecasts that for the hard spring wheat area future acreages may be expected to be sown to hybrid wheats and to those of the most desirable types.

In this spring wheat area, over a goodly portion of it, it would not be easy to substitute another satisfactory cash crop to supplant wheat. Also in this spring wheat area disease takes a severe toll of the wheat crop. Comparing wheat yields and production of the four Northwestern spring wheat states, Minnesota, N. Dak., S. Dak., and Montana, with that of the rest of the country, I have estimated that for the five years, 1923 to 1928, the wheat production of the four states has lagged behind that of the rest of the United States a total of 135 million bushels. That is to say, yields per acre have been enough lower in the four spring wheat states, in comparison with the other states, to have made this relative difference in production. One can not say whether the spring wheat area faces greater weather hazards in wheat production than the average of the rest of the country. If it does then a portion of this 135 million bushels deficiency may be considered a permanent assessment levied upon the four states by climatic conditions.

Effect of a Resistant Wheat upon Total Production.

Ceres wheat, as you know, is a new variety derived from crossing Marquis and Kota. It possesses a considerable portion of the stem rust resistance of its Marquis parent. It is susceptible to smuts and to other diseases. Comparisons are available in over 100 cases between Marquis and Ceres for the years 1923 to 1928, in the four states. Detailed yields of Ceres and some of its related selections are presented in this report by Mr. Clark. Basing judgment on ratio of yields in the experiment plats and extending such ratios to field conditions, I have estimated that had the Ceres variety been grown in the four states from 1923 to 1927, the total production for the five years would have been relatively speaking 194 million bushels in advance of the rest of the country. If weather hazards in the spring wheat area are comparatively exacting as is commonly thought, these results apparently indicate that also in other regions marked positive benefits may be expected from wheat breeding work.

Other selections have been made from the Marquis-Kota cross already mentioned which have definitely outyielded the Ceres variety. As a result of 62 comparative experiments in four states extending

over three years, Marquis averaged 20.8 bushels, Ceres averaged 25.4 bushels and the selection, 1656.84, yielded 28.0 bushels.

The yield of 1656.84 was very significantly greater than the yield for Ceres in the 62 experiments. Associated with this greater yield is found a consistently greater resistance to rust. Comparative rust readings are not complete for these experiments but there is no question about the different behavior of the two wheats with respect to rust. In 18 experiments in North Dakota in 1927 Ceres, 1656.84 and 1656.85 were grown comparatively. 1656.85 is a sib selection of 1656.84. Yields for these three were, in order, 26.7, 29.9 and 33.0, bushels per acre, and corresponding rust readings were 14, 7 and 4 per cent. The yield of 1656.85 is very significantly greater than that of its sib, 84. The difference in the amount of rust carried is significant with odds of 67:1 that 85 had a lesser amount of rust. The data do not allow a decision whether the difference in yield can be accounted for by the very small difference in amount of rust. Agronomists and pathologists are not in the habit of thinking that such apparently slight rust differences as 3 per cent are sufficient to result in differences of 3 bushels per acre. We are fortunate in the comparison of these three wheats in that they are closely related and evidently are much the same in their reactions to other diseases.

In the western part of North Dakota where differences in rust between 84 and 85 were less pronounced, yield differences become of zero order. This indicates that in the eastern part of the state very small differences in rust brought about yield differences of considerable magnitude but the case is not proved for with the change in geography, other elements may have entered in which affected yield. The problem of the influence of stem rust upon yield has really been given very little study. A series of yield comparisons between two varieties showing differences in rust readings may mean very little as other diseases may be present tending to emphasize or minimize the differences due to rust. To conduct any exact studies as to the effect of stem rust upon yield one would require for the comparison two varieties or selections quite alike except as to their reaction to rust. Failing in having two such wheats it would be necessary to measure the effect of other yield inhibiting factors to allow the partial correlation between stem rust and yield to be determined.

Inherent Yielding Capacity

Aside from all disease effect, the inherent yielding capacity of different wheats must be considered. This problem is of far-reaching importance in any extended breeding program such as is contemplated by this Conference. The two main demands upon a cereal variety, particularly upon wheat, are quality and yield. Breeding for resistance to disease has for its principal object an increase of yield but breeding for freedom from disease may accomplish its object only in part for one may conceive a variety of wheat made up of quite

healthy plants entirely outyielded by another variety composed of healthy or even somewhat diseased plants. Accurate knowledge on this point is largely lacking. There have been variety trials without limit, but an accurate analysis of yield belongs largely to the future. Mention of some excellent work done along this line by Engledow in England is in order and some valuable studies have been made in Russia.

Nilson-Ehle in Sweden is strongly of the opinion that the character of yield is just as definitely genetic as that of length of maturity or even height of plant. He believes that the high yield which is commonly found associated with the longer season varieties may be transferred by breeding to shorter season varieties which are commonly comparatively low yielding. His discussion along this line is very suggestive and worthy of experimental studies. Nilson-Ehle's contention seems to be borne out, at least in part, by certain hybrid selections made by J. A. Clark from a Marquis x Kanred cross. One of these selections has been named Reliance. The susceptibility of Reliance to stem rust does not allow worth-while comparative yields to be made where rust is present but under the nearly rust-free conditions which usually obtain in Montana Reliance and its sibs have yielded significantly higher than the Marquis parent. In this case is it not likely that Kanred wheat has a yielding capacity inherently higher than that of Marquis and that this has been transferred to the Reliance hybrid selection and its sibs? It may be that the higher yield of Reliance is a direct consequence of some other character, such as greater stooling capacity. Even if this were the case the practical result might be much the same.

Some of my own results indicate that selections apparently identical in appearance may possess different yielding capacity which difference is not brought about by a reaction difference to disease. One hesitates to draw definite conclusions in comparisons of this sort without careful studies by a pathologist as some disease may be present not easily recognized. Unfortunately those selections having the lowest apparent yield have not been compared long enough with the most promising selections to warrant conclusions. The selections which allow comparisons to be made because of sufficient number of experiments gave early indications of promise from one or two yields which promise was not maintained in later trials. Eight comparisons are available between 1656.84 and 1656.47, two sister selections from a Marquis-Kota cross. The selection 84 outyielded 47 in the 8 cases with an average of 5.5 per acre. The difference is of marked significance with odds of 368:1. The resistance of 47 to rust is evidently about the same as that of 85. Another selection, 1656.83, shows lower yield than 1656.84 in the 20 available comparisons. The difference is 2 bushels per acre with odds of 262:1 of a significant difference. A comparison of 1656.84 and 1656.81 is of particular interest for in this case 1656.81 usually carries less rust than 1656.84. In 27 cases where an appreciable amount of rust was present 84 carried

more rust than 81 in 24 of the cases. In 27 comparisons the two wheats averaged 12 and 6 per cent of rust. There are 31 comparative yields available for the two wheats. While the average difference is but 1.6 bushels this difference is significant with odds of 332:1. Aside from their difference in reaction to stem rust these two selections appear so similar, except as to yield, that any possible difference between them would probably escape detection. I am confident that data could be secured showing differences in yield between these selections from my Marquis-Kota material much more pronounced than those which have been cited, but the low yielding selections tend to be eliminated early from the experiments before enough data have accumulated to make significant comparisons possible.

Importance of Breeding for High Yield

My purpose in citing this evidence is to show the necessity of breeding for high yield in addition to breeding for disease resistance. It would be unfortunate if so much attention were to be centered upon freedom from disease that high yield came to be neglected. Both yield and quality must receive prime consideration in any breeding program. If these elements are neglected at first the maximum end results are greatly retarded. In breeding for disease resistance the desirability of using at least one high yielding parent in the cross must be given proper consideration. If the disease resistant parent is also high yielding the advantage is two-fold as the hybrid selections are then less apt to be handicapped by carrying factors for low yield. Breeding wheat is alluring work but when three or four major demands must be met in the production of a suitable variety let us not deceive ourselves that the task is an easy one.

Breeding for Adaptability

There is still another aim in breeding which, while somewhat less specific than the foregoing, is of considerable importance. I refer to the production of varieties having wide geographic adaptability. Aside from its susceptibility to stem rust, Marquis wheat seems widely adapted. Part of this adaptability is due to obvious morphological characters, such as strength of straw, and part is not so easily explained. A variety like Red Bobs or Hard Federation is rather rigidly restricted to non-rust areas but evidence from crosses indicates that aside from rust susceptibility Hard Federation must be restricted to areas of certain climatic conditions. The variety Marquillo is evidently of considerable interest in this respect. This variety in the region where the experiment stations of Crookston, Morden and probably Langdon, are located has done remarkably well. For four years at Crookston Marquillo has exceeded Ceres in yield and has stood second only to Mindum. There may be other localities where this variety is particularly adapted but that need not enter into this discussion. As one proceeds

southwest it is not evident that Marquillo is adapted. Even at Fargo, only 60 miles from Crookston, its lack of adaptability is in evidence for as an average of 9 experiments covering 6 years it is significantly lower yielding than Ceres, with odds of 45:1. Marquillo has carried somewhat less rust at Fargo than Ceres. With 1656.84 yielding significantly more than Ceres at Fargo, largely because of difference in rust resistance, the lack of adaptability of Marquillo at Fargo becomes even more obvious. A total of six plat yields of Marquillo are available at Mandan and Dickinson and here the odds are on the horizon of significance that Marquis has outyielded Marquillo. It is quite possible that Marquillo is unable to resist heat as well as other varieties but further studies are necessary for any final opinion. Obviously any natural wheat area possessing widely adapted varieties demands fewer varieties to fulfill its needs. A minimum number of varieties in an area is an economic advantage in the providing of pure seed and in marketing.

Summary

Attention is called to the fact that the acreage of wheat in the United States sown to hybrid varieties is comparatively small. The acreage sown to Marquis exceeds that of other hybrid varieties.

A study of wheat production in Sweden and New South Wales indicates that our relatively small hybrid wheat acreage is not necessarily due to the fact that more wheat is raised than domestic consumption demands. The export wheat of the United States has been a mixture of types and has not been of such a quality as to command premiums at foreign terminals. Our export wheat has not been of enough volume to yield a considerable per centage of our national income.

The hard spring wheat area of the United States lags behind the rest of the country in yield per acre, and thus in comparative production. If varieties in the hard spring wheat area were grown which were more disease resistant than those which have been grown, then yields per acre of spring wheats would probably be greater than yields of other wheats in the rest of the country. This is indicated by comparative yields between Marquis, Ceres and other selections not yet named.

Data are presented indicating that even very small apparent differences in amount of rust between varieties may affect yields very materially. If the evidence as given is reliable, it is likely that greater losses due to rust have been suffered in the past than is commonly believed. Also it is possible that the amount of rust present as shown by pustules may fall far short in measuring loss of crop produced.

Evidence is presented indicating that selections, even when closely related, may have different inherent yielding capacities without regard to disease. Assuming that varieties possess different yielding capacities, it is evident that in breeding as much attention should be paid to inherent capacity of yield as to freedom from disease.

Attention is called to the fact that certain varieties are less widely adapted than others. In producing new varieties, it is of economic value to breed for wide adaptability as when this is done fewer varieties will be necessary for any natural wheat area.

Because of the several major demands of a desirable wheat variety, the production of desirable varieties is a matter of great difficulty.

POSSIBILITIES AND DIFFICULTIES IN THE FIELD OF RADICAL WHEAT CROSSING.

Edgar S. McFadden

The subject assigned to me for discussion is "Possibilities and difficulties in the field of radical wheat crossing". I have taken the liberty of turning this subject around somewhat in that I will discuss the difficulties first, and then spend the remainder of the time allotted to me in a discussion of the possibilities. I have done this for two reasons; because I feel that in any radical venture it is always a good policy to first consider the difficulties with which one must contend, and because, in this particular case, there is practically no limit to the possibilities, and should I attempt to discuss them first, there might be no time left for consideration of the difficulties.

In my various attempts at radical crossing involving wheat, the difficulties that have been encountered can be classed under two heads. The first of these, for lack of a better name, I will call "genetic inaffinity", while the other is linkage of characters. Genetics inaffinity is probably due to differences in the number or general nature of the chromosomes, and may result in complete failure to effect a cross or in partial or complete sterility of the first or following hybrid generations. For instance, in the writer's experience, all attempts to produce a cross between the <u>vulgare</u> wheats and Agropyron species such as quack grass, western wheat grass and slender wheat grass have met with complete failure. On the other hand, it is a rather simple matter to produce a cross between the <u>vulgare</u> wheats and rye, but in this case, the first generation hybrids, in the writer's experience, have always been completely sterile except when back-crossed with the wheat parent. In crosses of <u>vulgare</u> wheats with durum, Poulard, and Polish wheats and with emmer, partial sterility results in the first hybrid generation, and both partial and compoete sterility in some of the plants of the following generations. Genetic inaffinity can, in some cases at least, be overcome by crossing on a large scale.

The problem of linkage of characters is in some cases more difficult to deal with than that of genetic inaffinity. In numerous crosses made between our hard red spring wheats and the rust resistant durums, the character of resistance to stem rust has proved to be closely linked with certain kernel and spike characters of the durum wheats. I have studied several hundred thousand F_2, F_3, and F_4 plants from such crosses without finding a single case of this linkage having been broken. However, I am not going to say that the linkage cannot be broken. It probably **can** be if sufficient numbers are employed and nature is given sufficient time to take her course.

In two different crosses between *vulgare* wheats and emmer, linkage of characters that was quite apparent in the F_2 and F_3 was successfully broken in the F_4. I refer to crosses of Marquis and an unnamed wheat with Yaroslav emmer.

The possibilities of wheat improvement from radical crossing are practically unlimited. The time allotted to me will permit discussion of the possibilities of a single radical cross, that of Marquis wheat with Yaroslav emmer.

Yaroslav emmer possesses several characteristics which would be of great value in our hard spring wheats. Chief among these characteristics are a high degree of resistance to both stem and leaf rust, resistance to tip blight, a thick, strong chaff which prevents shattering of the kernel, tough, flexible stems that are resistant to breaking by wind and hail, and narrow leaves of a dark blue-green color, characteristics that are often found associated with drouth resistance.

The problem of transferring all of the above named desirable characteristics of Yaroslav emmer over onto our hard red spring wheats was undertaken by the writer in 1916. It was planned first to combine all of these characters in a single variety if possible, which variety could later be used as foundation from which to develop other special purpose varieties possessing the same characteristics or as many of them as was necessary to meet the end in view. Several crosses between Yaroslav emmer and our leading commercial varieties of hard red spring wheat were attempted. Only one of these crosses, that with Marquis wheat will be considered in this paper. In this cross, Marquis was used as the pollen parent and Yaroslav emmer as the seed parent. A single F_1 hybrid plant resulted from this cross. This plant produced a great number of culms which bore spikes, but all of the spikes showed more or less sterility. A total of something over 100 seeds was produced by this plant. From this seed, approximately 100 F_2 plants were grown in 1918. These plants were all decidedly unpromising. After making careful observations on the plants of this generation, I became convinced that it was going to be next to impossible to ever segregate anything of real value from the material by ordinary methods of systematic selection. It was decided, therefore, to harvest and thresh the material in bulk, and grow it as a "mixed population" for several generations so as to give more promising types a chance to make their appearance. Accordingly, the material was grown, harvested, and threshed in bulk at Highmore in 1919. This proved to be a bad rust year, and all of the plants that did not possess a high degree of resistance to stem rust produced badly shrunken seed. This gave an opportunity to make a rather sharp separation of resistant types from susceptible types by mechanical means. The material was first threshed with a small nursery thresher with the cylinder speed reduced considerably so as not to separate the seed from the hull in the emmer types.

The threshed grain was then run through a Clipper seed cleaner with an upper screen of the right mesh to run off the seeds to which the hull had adhered. A rather coarse rectangular mesh was was used beneath which served to separate the plump seed from the slender types and seed that had been shrunken as a result of stem rust injury. The resulting plump seeds which represented, in large measure, the rust resistant types were then run through an Emerson Kicker which removed the long kerneled types, and left only the short, plump types. After the seed had passed through the different mechanical elimination processes described, only a fraction of one per cent of the original bulk remained.

Between four and five thousand F_4 plants were grown at Highmore in 1920 from the mechanically selected seed. This material was carefully observed during the growing season, and about 100 of the more promising plants tagged for selection and further study. These selections were later all discarded with the exception of six which appeared to be true vulgare wheats possessing all of the desirable characteristics of the emmer parent. All of these selections were free, or nearly so, from all recognizable diseases.

In the spring of 1921, the six Marquis-emmer selections were planted in progeny rows on rich garden soil on my farm near Webster, South Dakota. All of these selections remained entirely free from stem rust, and developed only a trace of leaf rust that year. Both Marquis and Kota which were used as checks developed considerable rust. The more promising of these original selections were reselected for kernel type, and these new selections were grown in progeny rows in 1922. On July 15, 1922, my farm was visited by a hail storm so severe that the state hail adjuster allowed me a 100 per cent loss on all crops. Upon inspecting my cereal nursery following this storm, I was greatly surprised to find that although the check rows of Marquis were almost completely destroyed by the hail, several of the Marquis-emmer selections were practically uninjured as a result of the strong chaff and flexible stems inherited from the emmer parent.

Since none of the progeny of the selections grown in 1922 were entirely uniform, new selections were made of the more promising plants from the rows that survived the hail storm. These selections were grown in progeny rows in 1923. Although none of these wheats had ever developed any stem rust since the first selections were made in 1920, it was not until 1923 that they were subjected to a severe test for rust resistance. A severe epidemic of stem rust developed early in July, 1923, and these selections remained entirely free from all traces of the disease at harvest whereas the check rows of Marquis carried a 100 per cent infection.

It was in 1923 that it first became apparent that although these Marquis-emmer selections had inherited all of the desired qualities of the emmer parent, they had also inherited at least two of its undesirable undesirable qualities as well. Conditions were expecially favorable for the development of root rot and black chaff that year, and the Marquis-emmer selections proved to be very susceptible to both of these diseases, having apparently inherited these defects from the emmer parent. After making this discovery, an effort was made to find individual plants that carried resistance to these diseases. About 50 plants were selected with this end in view. These selections were grown in progeny rows in 1924, but none of them proved to be very highly resistant to either of the diseases. However, some of them appeared to be somewhat more resistant than others, and a few of the more promising of these were saved for further testing.

Several F_1 natural crosses between the Marquis-emmer selections and other wheats grown in my nursery were found in 1923. An F_2 generation of these crosses was grown in 1924, and an F_3 in 1925. A study of this material reveased that there was no apparent linkage between susceptibility to root rot or black chaff and the desirable characteristics inherited from the emmer parent. In fact, no linkage whatever between any of the desirable emmer characteristics and any other characters was observed. Here was good evidence that it would be a simple matter to combine these desirable emmer characters with any other characters desired. After making this discovery, I became convinced of the great value of the Marquis-emmer selections for breeding purposes. Accordingly, what appeared to be the most promising of the selections was given the name of Hope and distributed to several experiment stations within the spring wheat area for use as a parent.

In addition to the natural crosses mentioned above, several artificial crosses of Hope and the related Marquis-emmer selections with other wheats have been made since 1923. A study of the F_2 and F_3 generations of this material has convinced the writer that the production of good quality hard spring wheats carrying all the desirable emmer characters and adapted to all conditions within the spring wheat area of the United States will not be a very difficult matter provided the necessary funds for carrying on the work can be raised.

Another desirable characteristic of the Marquis-emmer selections is their degree of resistance to both loose and stinking smut. Several attempts to infect these wheats with these diseases have met with complete failure with one exception, in which case three poorly developed smut balls were found at the base of one of the later spikes of a single plant. This individual plant had the appearance of being a natural hybrid with some other wheat, and it is possible that it may derive its partial susceptibility from that source. As to where these wheats obtained their resistance to loose smut and stinking smut, the writer is unable to say since the emmer parent is peculiarly susceptible to stinking smut, and Marquis is not very highly resistant to either of the smuts. Apparently these wheats came by their resistance to the smuts in much the same way that Columbus discovered America--largely by accident. Nothing is known as yet concerning the inheritance of resistance to either smut in these wheats, but it seems reasonable to expect that this characteristic will be inherited by at least some of the progeny in crosses with other wheats.

AN EXTENSION SEED PROGRAM

E. G. Booth

There are at least three problems to be dealt with in a good extension seed program. The first of these is closely allied to the work of the plant breeder and is really considered follow-up work. The objects of a seed program may be considered as follows:

1. To distribute the foundation seed of new and desirable vvarieties and to encourage a further increase of such seed.

2. To popularize and limit the number of varieties grown to those which meet the needs of the state as a whole.

3. To organize and supervise facilities to create and care for the demand for good seed.

Intensive and extensive work is necessary to carry through this program. There are many ways in which each end can be attained, and numerous methods of attacking the problems.

A very important question arises as soon as the first supply of seed of a new variety is sufficient to distribute to farmers. Should wheat seed, for instance, be distributed in small quantities of one peck, a half or whole bushel, or in quantities sufficient to seed five or ten acres? Most crop improvement associations and seed organizations favor the distribution of a reasonable quantity to each grower. Kiesselbach, in a recent article, comes to the same conclusion and it has been the experience in western Canada that the seed situation was materially improved after such a policy was adopted.

After the first lot of a new variety has been distributed, preferably under contract, a far more important consideration arises. Should the state-owned or controlled institutions continue to increase and distribute annually a few hundred bushels of foundation seed of each of such varieties? Here we have a matter less discussed and of great importance. We usually hear the objection raised that state institutions should not enter into the seed business or compete with private interests. It seems questionable whether the production of a few hundred bushels of foundation seed of each variety can be considered a competitive business practice. In fact, crop improvement men have agreed in many places that state control and increase of such limited quantities is highly desirable and necessary to safeguard public interest and to obtain the best results from the efforts of experimental institutions. Sweden early recognized the necessity of a state-wide organization to increase and distribute yearly a supply of foundation seed. The plant breeding department in Sweden turns over all the new varieties and re-selections for yearly increase to the Swedish Seed Association.

The seed growers of Canada owe the wide expansion of their activities since 1920 to the newly adopted policy of the provincial and federal experimental farms who annually sell large quantities of elite seed. This system of increasing the available supply of foundation seed has, to a large extent, replaced the idea of growers caring for seed plots, although experienced seed growers still produce their own elite or foundation seed from hand-selected seed plots.

The Canadian association started its work based upon the idea of a hand-selected seed plot. The early educational work accomplished much in developing this system and wonderful results were obtained. The real point which is worthy of note here is the fact that even though a remarkable group of seed growers were trained and used the seed plot method for grains, public interest was not aroused, nor was widespread use made of registered seed grain in Canada until state institutions virtually supplied the foundation seed and became actively interested in such work. It is not nearly so important for state institutions to provide continuous supplies of foundation seed for corn and potatoes. These crops are easier to rogue and keep pure by selection. Seed of these crops can be selected for a good acreage and the work is not so difficult as maintaining the purity of the small grains and flax.

There are three essential things for a crop improvement association to have at its command; (1) a supply of foundation seed, (2) competent inspection and grading service, and (3) a demand for its products.

There is an old saying that "musicians are born"and it seems equally true that others are fitted for different walks in life. There are too few one-hundred-per cent growers who understand purity and seed improvement to entrust them with the entire responsibility of producing supplies of foundation seed. Farmers who have a liking for seed work can be trained to be good seed producers but the number of such men is limited, and they are widely scattered. Even these men, after being trained and knowing how to handle seed plots, have a noticeable inclination to ask the state institution for elite seed. It is of course necessary for the state institution to distribute foundation seed which is nearly 100 per cent pure.

From the seed growers viewpoint, it would seem highly desirable for each experimental station to have a small seed farm. It would be possible then to grow a small quantity of foundation seed of each recommended variety for annual distribution. To safeguard the purity of such seeds, it is necessary to have someone actively supervising the growing, cleaning and shipping. Cleaning facilities are very important and should be quite complete and up-to-date. Growers seem satisfied to pay a substantially higher price for pure, clean, foundation seed. This should make such an undertaking largely self-supporting.

The second step in an extension seed program has been noted as an effort to limit the number of varieties and popularize those which meet the greatest need. A variety which is grown on an occasional farm or even in part of a county, because of some peculiar soil or climatic condition , is not considered in this outline. A local community or selected seed grower can afford to give attention to such a demand, but the activities of an extension program in seed work should be largely governed by the relative proportions and importance of the crop. This fact has been emphasized to meet the statement that there is a place for half a dozen varieties of wheat, and to keep them from being placed on the state list of recommended varieties. When such varieties are merely a fraction of the total crop grown, they should be dropped from the seed program. This statement should not be interpreted to include varieties which have serious objections from an agronomic viewpoint, but which nevertheless are grown by a good percentage of farmers because of some counter-balancing merit. If the farmers of a considerable area find they can grow an inferior variety at a profit because of some environmental factor, then it should be part of the seed program to provide the best seed possible of such variety to keep the crop on as high a paying plane as possible.

It seems desirable that we should have a state advisory committee of plant breeders and those doing agronomy work to pass upon the list of recommended varieties. Such a committee might also function for the control of naming and releasing new varieties. It is undesirable to have individual authority to release or name varieties in different departments, and at different stations within the state, even though such groups are under separate control. All this is put forth from the extension worker's viewpoint to assure unanimity of effort and recommendations. There is also a feeling among extension workers that such principles and practices are necessary to inspire confidence and establish a basis for the development of a seed program. The plant breeder and agronomist must obtain the confidence of growers through the county agent, if the extension division is to supervise such work. To insure such confidence, growers must not be disappointed in the purity of the foundation seed recieved from the institution nor must the institution bread faith by an unwarranted interduction of a new variety just at the moment the seed growers have managed to increase one variety to the saleable seed point. To keep faith with those men, it should be possible to establish practices and methods which will insure their protection as seed producers. Would it not be ddsirable to appraise such growers a sufficient length of time ahead, to prevent them getting caught with a seed crop which has suddenly lost much of its value because of high pressure publicity for a new variety?

Referring again to the purity of foundation seed, there is one other point to be considered. We frequently hear it said that the seed distributed by state institutions contains some impurities but is far ahead of the seed grown by the average farmer, and is, therefore, suitable for distribution. This is probably true when such seed

is sold to farmers who will use it for the production of commercial grain. The seed grower who is being trained by the extension worker to identify and rogue out mixtures while increasing seed will soon lose confidence in the work and those who are working with him if mixtures are sent out from the state farm. The idea that it is the work of extension forces to train a group of seed growers to purify seed by the use of hand-selected seed plots is more theoretical than practical.

So far, nothing has been mentioned about a program for popularizing standard varieties. The effort along this line is decidedly different, perhaps due to the density of population as well as environmental factors. The following are some of the methods which have been widely used to popularize standard varieties:

1. Varietal demonstration fields. (No accurate yield data.)

2. Varietal demonstration plots and fields with small plots or square-yard areas harvested for yield data.

3. In more recent years, rod-row trials have been used.

4. Fair exhibits and entries.

5. Standing field grain competitions.

6. Combined standing field and threshed grain competitions.

7. Meetings and institutes.

8. Bulletins and pamphlets.

9. Press publicity of all kinds.

The question arises as to which of these, or other methods not mentioned, should be used. The extension worker has limited time and funds, and as a resllt, all extension workers are keen students of methods to accomplish the most work and greatest good with the least time and expense. There has been a decided shift in extension activities in some states towards the use of more newspaper publicity. Recent investigational work by the U. S. Department of Agriculture, Extension Division, indicates rather clearly that there is considerable wisdom in laying more stress on publicity. Older settled provinces and states, with denser populations, which have built up crop improvement associations, have used the demonstration plot and accurate yield methods with surprisingly good results. There is a marked tendency, however, on the part of provinces and states, with less dense populations, to use the general demonstration field and concentrate on publicity. Both methods have advantages and merits. For conservation of time and funds, there can be no question that the large field demonstration coupled with thoroughly organized publicity is a highly efficient program. More and more, extension workers are realizing that publicity is the greatest sales force and medium of accomplishing the

desired end. Publicity must be based on facts and have an appeal.

This state possesses 225 weekly newspapers, and 8 dailies. Several hundred editors are seeking real news stories which have a local interest. If John Smith of Lakota grew a new variety of rust-resistant wheat and sold ten bushels more per acre than the neighbors, it is a real news story with a local name and flavor. If John Smith grew a number of rod rows for the local agent and the yields of the rod row trials are published in the local paper or a number of farmers are invited in to look over the plots, the local effect is of small importance Let it not be thought that this statement detracts in any way from the value of such work. It is fundamental work and provides the data for institutional workers to assume confidence in their recommendations. All the way along the line, up to the farmers, such trials are useful, but education in the field must precede the real benefit of this type of work. Perhaps there are communities ready for such work and it is surely not too much to assume that the public's confidence will gradually be gained elsewhere. It is also reasonable to expect that if full confidence is developed in the work of the state institution, such demonstrating and popularizing of varieties can be carried out directly through trained seed growers used as the basis for organized publicity. Rod row trials and plots for accurate yield data are essentially part of the plant breeding or agronomy program. From an extension viewpoint, they may be effective but expensive in time and funds when the regular force in the field are responsible for carrying out the work. A good news story with a local flavor reaches more people and involves less time and expense. It is true, however, that the effectiveness of a policy to popularize varieties by publicity requires skill and training on the part of the agents in writing for local papers. The story must not only be news but it must be written up in news style.

It is apparent that no one method of popularizing and standardizing varieties should be used to the exclusion of others. In Minnesota and Kansas and in eastern Canada, the intensive method of plot demonstration has been used. In western Canada, the program has been developed by field demonstrations and publicity. With scattered farms and less dense population, the plot method of demonstration does not appear to be very attractive to extension workers as a whole.

The third problem to be confronted in an extension seed program is to meet the demand for seed by organizing and supervising facilities. This is a most effective way in which the county agent can establish contacts and be of service to his community. The supply of certified or registered seed is usually inadequate and indeed scarcely necessary as seed for the bulk crop.

The North Dakota state and county seed program has been designed to meet this situation. The first step is to discover and train the small group of farmers who have an inherent liking for seed work. There are probably 100 such men in the state. It seems a logical thing to use these growers, excusively for the first field increase of foundation seed released from the experiment station. Only men who will care for the seed, keeping it pure and attending to certification details, will

eventually be included in this group. These men will soon become known as seed growers. The pure seed laboratory and extension force will both be instrumental in developing this work.

The seed from such a group of growers will be sold throughout the county and state to the wide-awake farmers who wish to obtain increased yields and extra profits by supplying what the market demands in the way of quality and purity. This second group of farmers who are generally leaders in their community must be depended upon to really increase a variety to the point where everyone can obtain the seed as commercial stock. The county agent then has two jobs; (1) to select and train a few foundation seed growers for the initial increase. (2) to assist in the transfer of the pure seed thus increased, to a larger group of leader farmers and to keep track of such growers by general encouragement so that eventually he will have large stocks of good seed for everyone in the community.

The extension program cannot stop at this point. There are two fundamental things to be done, (1) to provide a source of foundation seed. (2) To build up a demand for the pure seed produced. Many a good seed grower has lost hope because his field of marketing did not extend beyond his neighbors who would not pay a premium.

To create a demand, public interest must be aroused and simple means provided for easy exchange or purchase of seed. This is going beyond the county agent's work to the field of the state specialist. Plans to develop the marketing side of pure seed work must include field inspection, registration or certification, seeds lists, local seed centers, seed fairs and a close cooperation with the seed trade. Seed houses have desirable seed cleaning machinery and it should be possible to use such facilities in a well-organized state seed program. A summary of the program outlined may be briefly given as follows:

1. The production of foundation seed of approved varieties on experimental farms which is-

   (a) Produced under the supervision of competent workers,
   (b) Cleaned and stored under up-to-date conditions,
   (c) Distributed free from admixtures and
   (d) Recognized as elite or foundation registered seed.

2. Distributed to a group or select or approved seed growers through

   (a) Distribution to men who like seed growing and who will work with the pure seed laboratory and extension workers,
   (b) Field and bin inspection by a regular force and certified or registered, and
   (c) State lists as sources of certified or registered seed.

3. Further distribution to prominent farmers for general increase through:

   (a) Encouraging men who are leaders in the community to buy pure seed.

(b) Using such seed to provide large sources for general distribution.
(c) Encouragement and partial supervision of growing these large fields.

4. Popularizing and restricting the number of varieties through:

(a) Field demonstrations on the approved seed growers' places and with leading farmers,
(b) Systematic publicity with a local touch, and
(c) Crop competitions, public gatherings, fairs znd bulletins.

5. Developing demand and market facilities by:

(a) Field and bin inspection,
(b) Some special seed centers,
(c) State seed lists,
(d) A standarized system of binning, spouting, cleaning, drying and storing to develop approved seed cleaning companies out of the existing trade, and
(e) A sufficiently flexible handling system to encourage and develop handling of certified seed by the local seed houses.

MAINTAINING THE IDENTITY AND PURITY

OF WHEAT VARIETIES

H. L. Bolley

This text is not without merit. It is well known that the manufacturer now rightfully claims and enforces the right to do his own mixing and blending of raw products used in processes of manufacture. Further, it is a criterion of business economics that best quality products can only be made from raw products of high purity and quality. Such pure type raw materials, whether of wheat or of other produce, therefore command top market values. They set the level of prices for all similar raw products of lesser purity and quality.

The primary purpose of this meeting is to plan for improvement of wheat cropping through breeding of new production strains, varieties or kinds. This can be done. New and improved varieties have often been made and as often lost. There are now an almost unlimited number of such lost kinds.

Wheat varieties are probably quite as old as intelligent man. So true is it that great modifications as to kinds, varieties and strains now exist, that it is quite possible that intelligent methods of selective sorting from the great mixtures now existing is as likely to give worthwhile results as one may hope to gain from the genetic breeding or selective sorting of crosses obtained by pairing of parent plants of supposed pure lineage; for at best, in such crossing work, one but aims to intelligently jumble the existing characters of million year old lineages, and must yet make the selections and save the worthwhile ones for cropping purposes.

In whatever way, then, that the breeder makes his selections, the type must yet be proved of worth for human consumption. That there may be opportunity to do this, the kind must be saved, for a time, from the inevitable end as an addition to the great general population of wheat mixtures.

There are data in the various pure seed laboratories of this country to prove conclusively that there are essentially no pure wheat varieties in commerce in any of the general wheat producing areas. Here in the northwest spring wheat area, it is safe to affirm that no new variety sent out by its maker is held reasonably pure under general cropping for a time exceeding 3 to 4 years. Thus, by the time that a new variety becomes the general crop of any region, it can not be asserted with surety that any of the noticed merits or faults of that crop are in fact natural to or characteristic of the supposed variety.

Plant breeding with wheats has now reached such a stage of exact procedure that any type can be produced that the trade will pay for. It should, however, be considered as worse than criminal carelessness for public institutions to largely expand the present production of varieties,

if no proper steps are taken to maintain the purity of kind until proved of merit, or if no method is devised to so safeguard the further seed increase, distribution and general cropping work that the sources of varietal admixtures shall be essentially eliminated. When this is well done, then, and then only, may we hope to reap the benefits which should accrue from the intensive advance in scientific methods of cropping now made possible by the chemist, physicist, agronomist, pathologist and plant breeder.

Every state now has the nucleus for such service and supervision in the possible systematized functions of its extension and pure seed divisions. I outline the steps as follows:

(1) When the plant breeding work of the experiment station has been consummated in a variety in sufficient quantity for distribution, it should be systematically, fairly and evenly distributed to farmers throughout the districts in quantities sufficient for proper seed plot or seed field work. This should be done under such contract as shall make it possible to withdraw or discontinue the varietal distribution as an approved variety or to aid in the rapid expansion of the production of the same under general cropping.

(2) The seed plots must be so guarded as to eliminate the possibility of the entrance into the increase crop of any varietal admixtures. This work falls nominally within the field of extension service.

(3) An official field inspection service follows. The duties of such service is to make complete records leading to registration and certification of the increase fields and their products; so that when quantity production of seed for sale is possible, it too shall represent a pure line pedigreed product. The general farming and milling fraternity then has a sound basis for work.

The North Dakota Agricultural College now has a part of this work well initiated, the essential steps of which are as follows:

(1) The authorized increased seed from any variety is sent out under contract between the director of the experiment station and the grower and under the number and varietal name as recorded in a given department of the experiment station.

(2) At the time the seed for the seed field or seed plot is distributed, the farmer is given instruction how and where to sow to avoid disease, weeds, varietal admixtures, etc.

(3) The county agent, or other service men of the institution, then keep in touch with the farmer and give such advice and aid as to roguing harvesting, threshing, storing, etc. as shall insure that the seed for the farmer's increase crop of the second and following years shall be of sound pure type.

There is no valid reason why wheat breeding work may not be greatly expanded and so pushed that results may not bring greater prosperity for all wheat farmers and their cooperating business allies and associates.

NEW WHEAT VARIETIES FROM THE POINT OF VIEW OF THE COMMERCIAL MILLER

M. A. Gray

I desire to congratulate those who are responsible for calling a meeting of this kind at this time. I doubt if it would have been possible ten years ago to gather a group of individuals interested in a program of wheat improvement. The large number present affords the best kind of an index of the possibilities that lie before us. This group of so many diverse interests implies a desire for cooperation, and I am sure we are convinced of the necessity of attacking a problem of this sort in cooperative spirit. Before beginning my discussion proper, may I not suggest that this conference be made into an annual affair? Certainly meetings of this sort consitiute clearing houses for discussion of things accomplished in the past and afford enthusiasm of future possibilities.

The problem of making a satisfactory flour is one of considerable difficulty. I believe I am speaking accurately when I say that the flour produced in the past by the mills of the Northwest won a rather remarkable reputation for this territory. Fortunately this reputation still remains with us in a large measure. In years past the quality of the flour milled in the Northwest from wheats grown here had unusual merits and was in great demand. This condition was particularly true before the large increase in production of the wheat in the Southwest. At the time when the flour of the Southwest entered the eastern markets it was not very choice and the baking trade, and especially the housewife, did not have much confidence in it. For reasons perhaps not very well understood there has been a change in attitude toward the flour of the Southwest. The competition at the present time between flours from the two regions is very keen. This is shown by the fact that in the eastern markets flour from the Southwest sells almost on a parity with our own flour. This is in marked contrast to the past when flour from hard red spring wheat commanded a premium of from $1.00 to $1.25 per barrel. This situation faces the miller, and in order to run his business profitably he is forced to recognize facts of this sort.

I am presenting these facts to you to show you that if millers seem to be very discriminating and exacting in regard to new varieties of wheat, a definite reason exists for taking such an attitude. As long as the mills of the Northwest are faced with such keen competition it is of the first importance that the wheats entering into their mills be of a certain grade. If this were not the case you can readily see that the reputation which mills of the Northwest have at the present time might easily be lost. It is necessary that we look at the wheats that we purchase very critically. The wheats that we mill must measure up to

certain requirements and must have a certain degree of uniformity; we can not afford to take chances on such important matters. It is very evident, I think, that if the millers started to use varieties of wheat that were inferior, that produced grades of flour which would sell at a discount in comparison with flours from the Southwest, that not only the mills would suffer, but that the farmer as well would have to take a discount in the price paid for his wheat. Frankly, the milling interests are run as profit-making enterprises, and if profits cease to be made the mills will naturally go out of existence.

Forty years or more ago the wheat almost universally grown was the old Scotch or Red Fife, and at that time it was considered the standard milling wheat of this country; not only was it considered the standard wheat, but it was probably superior in quality to any other variety grown. The variety Bluestem was introduced about 1892. The quality of this variety was also considered standard. Both of these varieties were largely replaced by Marquis over most of the hard spring wheat area commencing in 1913. Just why these wheats were successful for a certain period and then died out is rather uncertain. Perhaps it was due to the changing condition of the soil, to change of climatic conditions, to carelessness on the part of the farmer, or perhaps poor seed--whatever the reason there is no doubt as to the facts.

At the present time it seems possible that Marquis may follow the path of Red Fife and the other varieties. The millers have not been at all certain that some of the varieties that have been offered were equal to Marquis or Bluestem. It is not possible to consider many of these. However, it does appear that Ceres probably shows as good promise as any wheat produced in the last few years.

Dr. Ball pointed out this morning that the miller is interested in milling results and in quality. The quality of a wheat is of paramount importance. The miller is interested to have the wheat yield a reasonably high percentage of flour, and he is also interested in having the flour make a standard number of loaves per barrel of satisfactory quality.

The variety Kota was very much in the limelight a few years ago. It was being pushed by organizations which either believed it would supply a need of the farmer, or which believed that it was of commercial value in other ways. The millers were almost a unit that Kota wheat could not satisfactorily replace Marquis. It had certain peculiar characters which made the flour unacceptable by the flour buyer. Evidently Kota forms a considerably proportion of the wheat now grown in the Northwest, and it is pretty generally accepted on the markets. It is probably safe to say that efforts in promoting this variety should not be increased.

If the people who compose this Conference can develop a wheat like Ceres, it will be satisfactory to the millers. If it satisfied the millers a variety of this sort will likely mean a great deal for the Northwest.

I have tried to show you in this talk that the milling interests at present are laboring under certain handicaps. Whether these handicaps are so great that the milling interests can not get back to where they were a few years ago remains to be seen. Governor Sorlie is optimistic in feeling that we can go back to the position that the millers had some ten or fifteen years ago. I hope his optimism is well-placed, but personally I have doubts.

In regard to durum wheat, which has become a very large crop in the hard spring wheat area, the conditions having to do with its milling and quality requirements are entirely different. Durum wheat is ground into a coarse flour known as semolina, and this semolina, after being mixed with water, is formed into a paste, of which macaroni is a type. In order to meet market requirements macaroni must have the right color, it must retain its shape when cooked in certain ways, and it must not become mushy. The exacting demands of good restaurants and those of the foreign-born population must be satisfied. A durum wheat buyer finds it difficult to select s tisfactory durum wheat on the market. Not only is this true, but apparently the proportion of good durum wheat seems to be getting less and less every year. I can give no particular reason for this apparent increasing scarcity of satisfactory durum wheat, except that perhaps the durum wheat acreage has been entering into regions not adapted to growing a satisfactory sample. Kubanka is still a favorite durum variety. Mindum is a close second to Kubanka--perhaps almost equal to it. This variety was selected by the Minnesota experiment station. After these two varieties are mentioned it is doubtful if much more can be said in regard to desirable types.

I wish to put it emphatically before the Conference that millers in their criticisms of wheat varieties are governed entirely by the results secured at the mill and by their desire to satisfy the trade. Even though durum wheat meets an entirely different competition than common wheat, it also has to meet a critical competition. Although the manufacturers have expended a great deal of effort to increase the consumption of macaroni they have not been highly successful. The American-born citizen does not easily change his staple foods, and the large bulk of durum wheat products is still used by the foreign-born citizens or residents of the United States.

NEW WHEAT VARIETIES FROM THE POINT OF VIEW OF THE COMMERCIAL MILLER.

T. C. Roberts

I wish to assure the Conference that I welcomed the opportunity to come to this meeting and to become a part of it, even though my contribution is of little value, because I was sure that a thorough discussion of the topic that we have on hand here today would result in a program of very great benefit to all the industries involved.

I have given some thought to the subject assigned to Mr. Gray and myself, and have made an effort to analyze and define it, but I have not been able to come to decide that the commercial miller has any definite point of view with regard to new wheat varieties. I suspect that most of us as commercial millers are a bit inclined to treat or to approve of new wheats in the traditional way in which a Scotchman is said to treat his wife, that is, reluctantly. There are several reasons basic in the industry for this conservatism on the part of millers. First, the varieties raised in any given area usually come to the terminal markets pretty thoroughly mixed. For this reason, with the exception of perhaps one or two standard varieties, the millers may not have a clear idea of the characters of the minor varieties grown by farmers. Without a complete milling knowledge of the various varieties the miller feels that a very careful attitude should be taken toward any newly heralded variety. The commercial miller would be in a freer position to make definite statements with regard to wheat varieties if he were producing the final product. As a matter of fact, the miller manufactures flour, and as a consequence he must depend in turn upon the critical attitude of the baker.

In supplying flour to the baker the miller naturally comes into competition with other millers producing more or less similar flours. As a result of this a new variety, especially if it differs in milling and baking values from the standard varieties, is apt to have a disturbing effect upon the market with a consequent disturbing effect upon the miller. This has actually been the case in more than one instance.

It is rather self-evident that to the miller the first requisite of a variety of wheat is that it produce a satisfactory income to the farmer, for it is useless to expect a farmer to raise a wheat at a loss, even though it might appear of the greatest value to the commercial miller. If a variety is satisfactory to the farmer, if he can raise it profitably, then the mill has reasonable assurance of an adequate supply of wheat.

A wheat variety also must produce a sufficiently high yield of flour to enable the mill to compete successfully with other mills grinding wheats of a more or less similar type. Not only must the quantity of flour be satisfactory, but the quality also is of the first importance. It is probably safe to say that in the last few years the great increase of machine-made bread has an influence upon the demands made upon quality. Formerly, when bread was made mainly by hand, making bread was more or less of an art, and it took longer to discover the defects of a flour. At the present time, with the increasing mechanical processes, defects of character in a flour show up more rapidly in the various mechanical operations. Because of this a great demand has been placed upon the millers for flours of certain types, and of great uniformity. Not only this, but the change in the character of the flour is reflected back to the miller more rapidly than it was in previous years. I believe that the commercial miller may be a good deal of help to the man engaged in the production of new varieties of wheat by interpreting to him the commercial requirements of flours. I believe that the commercial mills are in a better position at the present time to aid the plant breeder in this work than formerly. One reason for this is that their laboratory facilities are more complete and better organized. Also, in the milling business the work is not distributed evenly throughout the year. Conditions are such that additional labor is necessary in the rush season. After the peak of work is over the commercial mill has facilities which might be utilized in co-operating with the plant breeder in determining what varieties are most satisfactory in a commercial way.

Pres. Coulter:-

I believe this finishes the program of talks and articles which we had outlined for the Conference. You will notice that it is indicated on the program that certain committees are to be appointed. It has been suggested that in addition to the three committees which are indicated, that a coordinate program committee be appointed dealing with the milling and baking phase of wheat improvement. For the general committee on wheat improvement I will appoint the following: Walster, Hayes, Clark, Waldron, Aamodt and Stakman.

The committee having to do with milling and baking in the program of wheat improvement will be constituted as follows:
Bailey, Sherwood, Loomis, Mangels and Gray.

The committee on organization and cooperation will be as follows:
Freeman, Ball, Dinwoodie, Hume, Roberts, MeKee and Brentzel.

The committee on finances is:
Woodworth, Coulter, Ball, Boss, Trowbridge, Haw and Governor Sorlie.

I see now that the time is 3:15, and I would suggest that these committees meet immediately and try to report here at 4:00. Those in attendance at the Conference who have not received definite appointments on committees are asked to sit in with that committee in which he is most interested.

John Haw:

I would suggest that as a part of the action of this Conference an organization be formed from representatives of the four states, Minnesota, North Dakota, South Dakota, and Montana. I believe that a Conference of this kind should not be allowed to adjourn without forming some sort of an organization.

Dr. H. L. Walster:

I am heartily in accord with the suggestion made by Mr. Haw. This country is pretty well provided with national organizations, but I am of the opinion that we have too few regional meetings. Regional meetings of greater frequency would lead to a more intimate study of our special problems, and I believe that in developing regional meetings we would be developing a plan which would help us very much in the solutions of many of our problems.

Dean E. M. Freeman:

The aims and plans of this Conference, I believe, should be translated into some sort of action, not poorly considered action, but action which will receive careful consideration. Before much discussion will be profitable, I believe that it is necessary to get down to the work of the finance committee. However, before the finance committee can do much that committee must know what the other committees are contemplating. I wish to suggest that after the committees upon program and upon organization adjourn that they send representatives from their committees to sit in with the finance committee and give to the finance committee a report as to their findings. By doing this the finance committee will have a starting point.

Dean Freeman's suggestions were put into the form of a motion and carried.

Governor Sorlie moved that the Conference be made a permanent organization. The motion was seconded by Mr. John Haw, and was carried unanimously.

At this point the presiding officer, President J. L. Coulter, suggested that before proceeding further with the matter of permanent organization, that the committees begin their deliberations and that after the committees had reported further consideration of permanent organization be taken up.

Committee Reports. (1) Program.

It was suggested that in outlining the general program that the contemplated program for the U. S. Department of Agriculture and the one for the individual states be sonsidered separately. Dr. Hayes thought it advisable to make one unified program, in order to simplify matters, for both groups; later the two could be segregated. Chairman Walster stated that he had the Department's tentative program at hand, and proceeded to read it in its entirety. In discussing the tentative Department program as presented before the committee, Dr. Hayes stated that he considered the program satisfactory so far as routine procedure was concerned, but he did not believe that enough provision had been made for fundamental studies, except along physiological lines. He believed that sums should be provided for fundamental studies in genetics and with regard to disease-producing organisms. It was stated by J. A. Clark that the work contemplated in the suggested Department program was not provided for by present bills before Congress. The recommendations made by the Conference would have to be taken care of by bills to be introduced in the future. It would be impossible to secure legislative response for any work this season. Even so, it would be important to get the program outlined and agreed to as soon as possible in order that it be placed in the hands of the Budget Bureau in the comparatively near future. Dr. Hayes suggested a definite statement with regard to the studies that should be made relative to genetics and cytology. This statement is as follows:

"Personnel and support for a more adequate study of genetic principles which furnish a foundation for a breeding program. This support would make possible a fundamental study of the inheritance of individual characters, including reaction to diseases, the interrelations of characters in inheritance, and biometrical studies to determine the relative importance of manner of reaction to various diseases as well as the importance of different agronomic characters. Such studies are necessary in order to correctly formulate a breeding program".

The part of the program relative to the increase of breeding stations was discussed. Dr. Waldron pointed out that difficulties would be involved if one or more additional breeding stations were started in North Dakota. Additional stations would lead to duplication of work and isolation of workers. He believed that with three breeding stations already located in North Dakota, that the

new work contemplated in the durum area at Langdon should be in the nature of testing out the material produced by the crosses made at the other breeding stations, particularly at the central station at Fargo. It was the opinion of the committee that new breeding stations should not be established unless conditions seemed to be quite imperative. Central stations should be utilized for the making of crosses and for the production of the F_1 and F_2 generations. With regard to the amount of money needed for fundamental studies the committee came to the conclusion that $45,000 would be no more than what was needed. This amount would be distributed according to the following scheme:

(1) Fundamental studies on milling and baking methods, including methods and nature of processes $10,000; (2) fundamental studies in crop ecology and agricultural meteorology in relation to wheat production $10,000; (3) fundamental studies in genetics and cytology of wheat* and (4) fundamental studies on the pathogenes or organisms causeng the most important diseases, including the nature of disease resistance $10,000. Total $45,000.

The program committee recommended that the Conference give official sanction to the tentative program originally suggested, with the modifications indicated, plus the suggested studies for fundamental investigations in the scientific lines listed above.

Dr. E. C. Stakman moved that the program as outlined be considered as a Federal program and that the Conference support it as such. In addition, each state should work out a program for its own particular needs, which program could come before the program committee of the Conference at a later date and be given its official sanction if considered feasible. This motion was carried.

It was suggested that this committee act in an advisory capacity, and that for this purpose it could meet occasionally to advantage. In these meetings aid could be extended to the different states in formulating programs, and in acting in a suggestive manner to the Federal program as to the best methods of carrying it out. It was further suggested that the program committee be organized in such a way that each state be represented. For the present, the work of the program committee would be limited to the program of the wheat crop. Later, if considered desirable, the work could be expanded to include other cereals.

A report of Dean Walster as chairman of the program committee to the organization committee follows:

"We have considered the program of the U. S. Department of Agriculture, which calls for an annual expenditure of $40,000. From a study of this report it is evident that most of the money recommended to be expended is for rather routine work. Some of this routine work is in addition to that where similar work is already going on and part of it is an extension of routine work into new fields. The routine work suggested in the Department's program includes the work of plant breeding, variety testing at different

* Genetics and cytology of wheat $15,000.

stations, protein and milling tests, and a certain number of physiological tests. The committee believes that additional studies are needed upon four other subject groups, and the committee further believes that these subject groups for proper study will require essentially the same amount of money as is already recommended by the Department program. The recommended fundamental studies are upon the subjects of : (1) plant pathology, and under this would be included a study of the pathogenes causing the most important diseases, and a study of the nature of disease-resistance; (2) fundamental studies on genetics and cytology; (3) fundamental studies on milling and baking, including the nature of the processes involved; (4) fundamental studies on crop ecology and agricultural meteorology in relation to wheat production. There is needed for these fundamental studies, including the fundamental studies upon plant physiology already outlined in the Department program the sum of $85,000. (This is recommended to be assigned to the various subjects in accordance with the statement already given.) Up to the present time, comparatively little study has been made upon the chemistry of wheat, especially upon the chemistry of hard red spring wheat, or upon the genetics of chemical factors. After research work has been done, as suggested by this committee, we will be in a much better position to answer the question:Why is a certain field result obtained? To sum the whole matter up, it is the suggestion of this committee that the Conference be asked to support a large federal program calling for an annual expenditure of $85,000; in addition, it is recommended that eadh state formulate a state program in accordance with its own needs.

Report of Milling and Baking Section.

At this point the sectional program committee appointed to report upon milling and baking presented the following report by its chairman, Dr. C. H. Bailey:

1. Consolidate the data from various sources and attempt its analysis.
   - a Experiment stations of: Montana, North Dakota, Minnesota, South Dakota, Canadian Province, and Federal laboratories.
   - b Milling companies.
   - c State testing mill of Minnesota.
2. Work toward the end of developing uniform methods for the examination of:
   - a Bread wheats.
   - b Durum wheats.
3. To cooperate with and advise plant breeders in the testing of parental varieties and hybrids.

   a Analyze commercial practices and indicate their relation to the application of laboratory tests.

b Devise new procedures which disclose properties of commercial importance.

c Set upcriteria and indices to be used in interpreting milling and baking laboratory data.

The report of the sectional committee on milling and baking was accepted by the main program committee as an integral portion of the whole program. At this point Dean E. M. Freeman introduced the following resolution:

"While it is recognized that the support of an improved wheat breeding program lies largely in appropriation from Federal and state funds, attention should be called to the excellent opportunity that is afforded by the proposed work for private funds. Consequently it is the sense of these committees that the attention of the public should be called to the great value which would result if somewhat ample dunds were provided by a private individual or by a group of individuals."

This motion by Dean Freeman was seconded and unanimously carried.

At this point the Conference reconvened at 4:00 to hear the r_eports of the program committee and the other committees. The program committee, after having received reports from the sectional committee on milling and baking, and reports from the committee on organization, reported to the Conference as follows:

It is not possible for any committee, either large or small, to formulate an adequate program in 40 or 50 minutes for a half billion dollar industry. As a working basis we had a tentative program that had been worked out by officials of the U. S. Department of Agriculture. I am going to read that program, and then also furnish you the suggested additions that we made to it in committee. It was the sense of our committees that that which I am going to read be recommended by this Conference essentially as a program for these four spring wheat states. It was the further sense that each state should formulate a state program, and that this Conference should support such states programs and the federal program as fully as possible. It was suggested that the program committee serve in an advisory capacity, continuing throughout the year until changed in personnel. It was further suggested that the committee help outline and support the state and federal program, and in order to do this to the best advantage it was suggested that the program committee be organized in such a way that it carry members from each of the four states interested. The committee further suggests that this Conference invite all interested parties to participate actively in forwarding a more adequate wheat program for these four northwestern states.

It is suggested that work on the program be prepared sufficiently early so that it can go before the Budget Bureau in time to be introduced into the next session of Congress. It was reported to the Conference as a whole that the program committee felt that it was impracticable to formulate four separate state programs; it was probably unnecessary to do this in the main as each state could probably work out its own program to the best advantage. It was suggested that arrangements be made, if possible, to have the committee meet occasionally to consider the program further, to act in an advisory capacity, for its efficient conduct. It was suggested further that the program committee give its attention to the possiblility of further support to the agencies already set up in the several states in this area having to do with the testing of wheat varieties and the production of new hybrids.

The report of the program committee as herein outlined was adopted. The following motion was introduced by Dean E. M. Freeman:

> "I move that a program committee of three individuals be appointed from each state, three from the Department of Agriculture and four consulting members from Canada, one each from the provinces of Manitoba, Saskatchewan and Alberts, and one representing the Dominion as a whole, to make plans for campaigns, programs and for future conferences;"

which motion was seconded and carried.

President Coulter asked for a report of the Finance Committee. Mr. R. P. Woodworth, chairman of the committee, reported that the program which the representatives of the program committee had sent down to them had been talked over and approved in a general way. It was reported that no considerable amount of money could be made available for the present year, either from legislative or private sources. It was pointed out that in different states it might be possible to secure from the state treasuries emergency funds which could be put to use in the comparatively near future and that even a limited amount of funds would be desirable this present season in order to allow the wheat improvement program to go into full force the following year. Part of these funds could also be used to advantage in allowing the committees to meet to give further attention to the development of the program. It was also suggested that a report be prepared of the present Conference. It was moved that the chairman appoint a committee of one representative from each state, together with one from the Department of Agriculture--a committee of five, which would be requested to report tonight plans for permanent organization, and second, to give definite suggestions as to complete personnel of this program committee, after the dinner in the evening. This motion was seconded and carried. President Coulter appointed Dean Freeman, Dean Walster, Prof. Clyde McKee, A. N. Hume, and Dr. C. R. Ball.

At 5:00 o'clock, the Conference adjourned from the Green Room to meet at 6:30 for dinner at the Chamber of Commerce. Attending the dinner, in addition to those at the Conference, were a number of representative business men from Fargo and farmers from adjacent localities. The Chamber of Commerce courteously acted as host to those from out of town attending the Conference. Dean H. L. Walster presided at the dinner. Mr. W. P. Chestnut, Secretary of the Chambdr, welcomed the members of the Conference to Fargo which welcome was answered by President J. L. Coulter. The following toasts were responded to.

Modern science and modern crops. Dean E. M. Freeman.
Ye editor looks at the wheat crop. Dr. J. T. E. Dinwoodie.
Early wheat breeding days. Prof. J. H. Shepperd.
A better wheat crop in the elevators. Mr. R. P. Woodworth.
The railroad, the farmer and the wheat crop. Mr. John Haw.
Would the miller and baker like better wheat? Dr. C. H. Bailey.

Following the program of toasts, Mr. W. T. G. Wiener of the Manitoba Agricultural College responded informally for the Dominion of Canada.

Dean E. M. Freeman, Chairman of the committee on permanent organization reported as follows:

1. Officers: President, J. L. Coulter; Vice-President, Andrew Boss; Secretary-Treasurer, L. R. Waldron.
2. General program committee of nineteen. (This is to be composed of members from each of the four states concerned- each state committee to develop its own state program, three members representing the U. S. Department of Agriculture and four (consulting) members from the Dominion of Canada, the first representing the Dominion as a whole and one from each of the prairie provinces):
   Minnesota: T. C. Roberts, E. C. Stakman and H. K. Hayes.
   North Dakota: L. R. Waldron, H. L. Walster and Roy Johnson.
   South Dakota: C. Larsen, A. N. Hume and J. T. E. Dinwoodie.
   Montana: Clyde McKee, L. D. Kurtz and J. A. Wilson.
   Dept. of Agr.: O. S. Aamodt, M. A. McCall and J. A. Clark.
   Dominion of Canada: W. T. G. Wiener; Manitoba: C. H. Goulden.
   Saskatchewan: J. B. Harrington; Alberta: Robert Newton.
   H. K. Hayes was appointed general chairman of the program committee.
3. Finance Committee of five: Dan Wallace[1], Chairman, J. L. Coulter, W. C. Helm, John Haw, J. T. E. Dinwoodie.
4. Executive Committee of five composed of the three officers named and the chairman of the program and finance committees.

After a rising vote of thanks by the visiting members in appreciation of the courtesies shown by the Fargo Chamber of Commerce and by the North Dakota Agricultural College, the Conference adjourned.

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[1]Selected later. Editor, The Farmer, St. Paul, Minn.

(This report edited and compiled by L. R. Waldron, Secretary.)

A PROGRAM FOR BREEDING HARD SPRING WHEATS, AND RESEARCH FUNDAMENTAL THERETO, FOR THE NORTH-CENTRAL STATES

INTRODUCTION

Hard red spring and durum wheats are produced chiefly in Minnesota, South Dakota, North Dakota, and Montana, where spring wheat is an extremely important crop.

A breeding and improvement program of considerable extent is under way in most of the States named. It is universally recognized, however, that this program is not at all adequate to the needs of the situation as it now exists. Accordingly, the first annual spring-wheat breeding conference was held by sceintific and commercial representatives of these four States at the North Dakota Agricultural College, Fargo, North Dakota, on March 27, 1928. This conference tentatively outlined what was considered to be an adequate breeding program and also a program of additional research fundamental to such a breeding program. It created a permanent organization to complete the program and to make arrangements for cooperation in financing it.

The program proposes, first, the fullest utilization of existing facilities at State and Federal stations and substations, and, second, the establishing of additional facilities where needed for a complete and properly distributed breeding and research program. The proposed breeding and research program will include:

A. Breeding better wheat varieties, by

1. Expansion of present breeding projects, using existing stations ($7,300),

2. Establishment of two additional breeding centers on two existing substations ($7,500),

3. Testing in State-wide farm nurseries,

4. Establishment of a large, centrally-located nursery for determining disease reactions under artificial epidemics ($4,500, includes 5 below),

5. Inspection of breeding material for disease, and

6. Expansion of laboratory facilities for quality testing ($8,000).

B. Research fundamental to the breeding program, as follows:

1. Studies in crop ecology and physiology ($17,000),

2. Studies on relations between pathogen, host, and environment ($10,000),

3. Studies in the fundamentals of genetics, including cytology ($12,000), and

4. Studies in the chemistry of the wheat plant, including kernel ($10,000).

While the initial emphasis is placed on wheat and the proposed program is for wheat breeding and improvement, and certain researches fundamental thereto, it is realized that there is need of similar work on the other cereals. Eventually the program might well be extended to include oats, barley, rye, and flax, other important grain crops in the area. The fundamental research noted above should be applicable in large measure to the breeding problems with these other crops.

A. BREEDING BETTER HARD SPRING WHEAT VARIETIES

1. Expansion of present breeding projects, using existing stations ($7,300)

The present series of stations and substations in these four spring-wheat States covers the area fairly adequately, except for the two deficiencies mentioned in chapter 2. These stations should be more uniformly and efficiently utilized, however, for testing purposes. The proposed expanded cooperative program will provide for much more uniform and complete tests on all stations, and therefore utilize these present facilities much more completely and efficiently. To determine completely the adaptations of the numerous new selections requires adequate testing over the entire area, which is not now possible.

In Minnesota an extensive cooperative breeding program on hard spring wheats and durum wheats, and a lesser one on hard red winter wheats, are under way, including hybridization for resistance to stem rust. A cooperative cereal disease nursery of limited scope is conducted as a part of this program. In this nursery, varieties and selections are tested for resistance to stem rust, leaf rust, bunt, loose smut, scab, and various foot-rots. The breeding progenies are compared in nursery and field plats at St. Paul, and also at Waseca, Morris, and Crookston, representative of the principal wheat-growing areas. Milling and baking experiments are conducted on nursery and plat material. Some independent experiments on methods of determining quality have been made. Present personnel already has produced more breeding material than can be adequately and widely tested for agronomic and other values.

It is proposed to add funds to provide for the necessary additional nursery and field testing at St. Paul, Crookston, Morris, and Waseca.

In South Dakota, no definite State breeding program is under way. One private breeder, formerly in cooperative employment by Federal and State agencies, has made considerable progress in developing disease-resistant wheats. Independent varietal tests are conducted at the State station at Brookings, and the substation at Highmore. This work was cooperative with the U. S. Bureau of Plant Industry previous to June 30, 1920. An additional cooperative breeding center located in the principal spring-wheat-producing section of South Dakota is to be established, as indicated under chapter 2 below. To provide for adequate State-wide testing of the material produced at this breeding center, it is proposed to allot funds at Brookings, Highmore, and Eureka (State stations), and at Ardmore and Newell (Federal stations).

In North Dakota a partly cooperative program is under way similar to that in Minnesota, but less extensive. The disease nursery is not included, dependence being placed on natural field infection. Selections developed are tested at the State Experiment Station at Fargo and at the substations at Dickinson, Edgeley, Langdon, and Williston, and at the Northern Great Plains Field Station at Mandan, the more important ones in both nursery and plats. Promising nursery material was placed by State agencies with farm cooperators throughout the State in 1927. Independent milling and baking experiments are conducted, and also some work on methods of determining quality. One new breeding center for durum wheat is provided under chapter 2 below. For State-wide testing of the material from this center and the large amount of hard red spring material already available, additional funds are needed at Fargo, Dickinson, Edgeley, Hettinger, and Williston (State stations), and Mandan (Federal station).

In Montana a cooperative program is under way which includes breeding operations and nursery tests at the State Experiment Station at Bozeman and at the substations at Moccasin and Havre, and plat tests at these stations and at the substation at Huntley. The material already available is more than can be handled adequately. The proposed expansion provides for adequate testing at Bozeman, Havre, Huntley, and Moccasin, covering the State of Montana, and at Sheridan, Wyoming, for the adjacent similar part of that State.

The funds for the proposed expansion are indicated below in the attached budget.

2. Two additional breeding centers ($7,500)

Two additional wheat-breeding centers are needed, utilizing substations already in existence, if possible. One of these centers should be located in northeastern South Dakota, preferably at the U. S. Forage-Crop Field Station at Redfield.

The other should be in the durum area of North Dakota, preferably at the Langdon Substation. These two wheat-breeding centers will be used mainly in testing selections of various crosses for yield and for disease resistance, and for providing rod-row and plat material for milling, baking, and chemical studies. The main portion of the hybridization and the early-generation selection should be done at the chief Federal and State stations. Some hybridization, the growing of the F_1 generation, and growing, studying, and making selections from the F_2 generation, may be done at the two additional breeding centers.

3. State-wide farm nurseries

These tests of promising varieties and selections will be made on private farms well distributed over each State, especially in those sections not represented by a station. This work preferably should be done in cooperation with the College Extension Service. As far as possible, therefore, the tests should be located favorably for supervision by county agricultural agents, Smith-Hughes teachers, or other responsible and well-trained persons. It is recognized that these tests are a State function, and no Federal funds will be devoted to them.

4. Establishment of a large, centrally-located disease-testing nursery ($4,500, includes 5 below)

A central, large-scale, disease-testing nursery should be established. This nursery should provide facilities for testing all promising selections from the different breeding centers for reaction to the prevalent physiologic forms of the important diseases. Provision should also be made for the maintenance of cultures of the more prevalent physiologic forms of the important disease organisms in sufficient quantity for the use of the cooperating plant breeder.

5. Inspection of breeding material for diseases (Budget item included in 4 above)

Provision should be made for inspection of all the breeding material in the various nursery and plat experiments to determine the percentages of disease infection. The different physiologic forms of the important disease organisms which occur at each of the various stations also should be determined.

6. Expansion of laboratory facilities for testing quality ($8,000)

Provision should be made for large-scale laboratory tests of nursery material in order to determine the probable quality and commercial value of strains in an early stage of their development. This applies particularly to crude protein and gasoline color values. The need for this increased chemical work can be met by enlarging the facilities already existing in the U. S. Department of Agriculture, and by making use of the plants of the experimental mills now located in the spring-wheat area.

Provision should be made for an increased number of milling and baking tests and for experimental manufacture of semolina and the edible pastes from samples produced under comparable conditions. Milling and baking tests for varieties and selections grown in field plats should be uniform for the entire area and the results should be made available soon enough after harvest to serve as a criterion for future sowings.

B. RESEARCH FUNDAMENTAL TO THE BREEDING PROGRAM

1. Studies in crop ecology and physiology ($17,000)

To breed new varieties most intelligently, more information must be available on the physiological effect of the different factors of environment (light, both quality and daily duration; temperature in its various relationships; fertility; moisture supply; humidity; etc.) on wheat varieties, both as reflected in final yield and in relation to disease resistance. A comprehensive study should be made of the distribution of present commercial varieties in relation to temperatures, rainfall, snowfall, soil type, and other factors of environment likely to have a bearing on adaptation.

Studies should be conducted on the effect of controlled temperatures, fertility, and light on the life history and optimum development of representative wheat varieties. The differences between varieties in their reaction to these factors and the relationship of these differences to the adaptability of varieties to different environments, should be determined. Information on these items would be of great value in a breeding program. Location not yet determined.

2. The relations between pathogen, host, and environment ($10,000)

Much work already has been done on the distribution and prevalence of different physiologic forms of stem rust of wheat, as well as on the reaction of host varieties. It is important, however, that further study should be given to physiologic forms of other pathogens, such as the bunt fungus, the leaf-rust fungus, the scab fungus, etc. The existence of physiologic forms of some other fungi is positively established, and for still others is strongly suggested. This information is far too meager to serve the needs of the proposed breeding program. The existence, the geographic range, and breeding significance of physiologic forms of all pathogenic fungi which attack the wheat plant should be determined.

A far more extensive program of research than has ever been undertaken should be directed along the lines of physiological conditions influencing disease development. The relations of moisture and temperature, for example, have an important bearing on resistance or on what appears to be resistance to disease. Further studies on these environmental factors should be carried out under controlled conditions in the greenhouse and correlated with weather conditions prevailing in the area concerned. A knowledge of the conditions most favorable for disease infection and development would facilitate the work very materially by furnishing a means of detecting degrees of resistance or absolute resistance in plants.

Studies should be made on the combined effects of two or more diseases. Very little is known of the conditions brought about by two or more diseases working simultaneously on the same plants. A selection or variety which appears resistant to several diseases under pure-culture conditions may not prove so when subjected to two or more of the pathogens at the same time. Location not determined.

3. Fundamental genetics, including cytology($12,000)

A knowledge of the wheat genotype and linkage groups is very necessary for the best operation of the extensive proposed program. Much greater progress has been made with corn, for instance. Genetic data now available should be carefully analyzed and conclusions drawn. Both qualitative and quantitative characters should be studied, for the former, even when of no evident economic value, may serve even better than quantitative characters of economic value in the analysis of the genotype. Emphasis should be placed, however, on the inheritance of quantitative characters of economic importance. Studies of inheritance almost necessarily should be accompanied by cytological investigations. This is particularly true with wheat where crosses between varieties belonging to different subspecies and with different chromosome numbers, possess such great potential economic importance.

4. Chemistry of the wheat plant, including the kernel ($10,000)

The cereal chemist in a plant breeding program can assist the plant breeders in selecting for quality. Better methods of examining samples which are more selective and are applicable to smaller quantities of material should be developed. For developing such tests, more knowledge of the fundamental chemistry of wheat and flour is needed. Location not determined.

PROPOSED ALLOTMENTS FOR THE FEDERAL PORTION ($85,000) OF THE INCREASED COOPERATIVE BREEDING PROGRAM:

RESERVES AND ADMINISTRATION ($8,700)

Department Reserve (2 p.c.)...	$1,700	
Bureau Reserve (1 p.c.).......	850	
Supervision, supplies, travel	6,150	$8,700

A. BREEDING BETTER WHEAT VARIETIES ($27,300)

1. Expansion of present breeding projects, using existing stations

Minnesota

St. Paul, Agr. Exp. Sta. (labor)	$600		
Crookston, Substation (labor)	300		
Waseca, Substation (labor)	300		
Morris, Substation (labor)	300	$1,500	

South Dakota

Brookings, Agr. Exp. Sta. (labor)	300		
Highmore, Substation (labor)	300		
Eureka, Substation (labor)	300		
Ardmore, U.S. Field Station (labor)	300		
Newell, U.S. Field Station (labor)	300	1,500	

North Dakota

Fargo, Agr. Exp. Sta. (labor)	600		
Mandan, U.S. Field Station (labor)	500		
Dickinson, Substation (labor)	500		
Edgeley, Substation (labor)	300		
Hettinger, Substation (labor)	300		
Williston, Substation (labor)	300	2,500	

Montana

Bozeman, Agr. Exp. Sta. (labor)	500		
Havre, Substation (labor)	450		
Huntley, Substation (labor)	300		
Moccasin, Substation (labor)	250	1,500	

Wyoming

Sheridan, U.S. Field Station (labor)	300	300	7,300

2. Establishment of two additional breeding centers

North Dakota

Langdon

1 Associate Agronomist	3,000		
Station expense	300	3,300	

South Dakota

Redfield

1 Associate Agronomist	3,000		
Station expense	1,200	4,200	7,500

4 and 5. Establishment of a central disease-testing nursery and inspection of breeding material for disease

St. Paul (Minn.), Agr. Exp. Sta.

1 Associate Pathologist	3,000		
Station expense	700		
Travel	800	4,500	4,500

6. Expansion of laboratory facilities for testing quality

Washington, D. C.

Laboratories, Bureau Agricultural Economics:

1 Miller	2,400		
1 Baker	2,400		
Equipment (macaroni manufacturing)	1,500	6,300	

Laboratory, Bureau of Chemistry and Soils:

1 Scientific Aid	1,500		
Equipment	200	1,700	8,000

B. RESEARCH FUNDAMENTAL TO THE BREEDING PROGRAM ($49,000)

1. Crop ecology and physiology

1 Physiologist	3,800		
2 Associate physiologists	6,000		
Equipment (temperature control apparatus, general apparatus, greenhouse equipment, etc.)	6,400		
Travel	800	17,000	17,000

2. Relations between pathogen, host, etc.

1 Associate Pathologist	3,000		
1 Assistant Pathologist	2,400		
Equipment (apparatus, greenhouse equipment, etc.)	4,000		
Travel	600	10,000	10,000

3. Fundamentals of genetics and cytology

1 Associate Agronomist	3,000		
1 Associate Cytologist	3,000		
2 Scientific Aids	3,000		
Equipment (cytological, laboratory, field, etc.)	2,000		
Travel	1,000	12,000	12,000

4. Chemistry of the wheat plant, including kernel

2 Associate Chemists	6,000		
Equipment (laboratory)	3,500		
Travel	500	10,000	10,000

Grand total..$85,000